SEPTEMBER 1910 VOL. 32 No. 9

THE JOURNAL
OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PUBLISHED AT 2427 YORK ROAD . . . . . BALTIMORE, MD.
EDITORIAL ROOMS, 29 WEST 39TH STREET . . . . . . NEW YORK

CONTENTS

The Journal is published monthly by The American Society of Mechanical Engineers.
Price, one dollar per copy—fifty cents per copy to members. Yearly subscriptions, $7.50; to members, $5.
Entered at the Postoffice, Baltimore, Md., as second-class mail matter under the act of March 3, 1879.

The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 SEPTEMBER 1910 NUMBER 9

THE JOINT MEETING IN ENGLAND

In his response to the address of welcome at the first professional session at Birmingham, of The American Society of Mechanical Engineers and The Institution of Mechanical Engineers, Dr. W. F. M. Goss, Vice-President of the Society, happily alluded to the spirit of federation that exists among English-speaking engineers and to the pleasure and profit to be derived from joint meetings of the two Societies. To say that this meeting afforded the greatest possible pleasure to the American visitors is but to state a fact, the true appreciation of which can be had only by those who were the recipients of the whole-hearted reception given by their English friends, their elaborate entertainment and provision for seeing the best that the country afforded, in industrial as well as historical features, and in its delightful social life.

THE OCEAN TRIP

The White Star steamship Celtic, bearing the party for the joint meeting, sailed from New York Saturday afternoon July 16 and arrived in Liverpool Sunday evening July 24.

The weather during the trip was good and the voyage was a time of rare enjoyment for the whole party. The ship's officers were gracious in their attentions and the committee of arrangements, Mr. Ambrose Swasey, chairman, had their plans perfected with the

greatest care and conducted the party up to the time of arrival at Birmingham by special train, when the travelers were placed in the hands of their generous and attentive hosts.

Not the least contribution to the pleasure of the journey was the program of the entertainment committee, Mr. Geo. M. Brill, chairman, which provided for games of bridge, deck games and tournaments, inspection trips about the boat and the following evening events:

Monday Evening, July 18 **Reception**

By the officers and past-presidents of the Society and chief officers of the ship.

Tuesday Evening **Illustrated Address**

By Worcester R. Warner, past-president, on What are the Astronomers doing.

Wednesday Evening **Musicale**

Thursday Evening **Illustrated Address**

By John R. Freeman, past -president, on Construction of the Panama Canal.

Friday Evening **Dancing**

Saturday Evening **Informal Entertainment**

Awarding of prizes for the games, tournament, etc.; music; a humorous address by James M. Dodge, past-president; and original poems by others.

The sailing list of the Society comprised over 150 members and guests who were joined by upwards of 100 others at Birmingham and London. There was deep regret that it had been impossible for President and Mrs. George Westinghouse to accompany the party and participate in the events to which their presence would have contributed so large a measure of completeness.

On the last Saturday of the trip the appreciation of courtesies extended by the ship's officers was shown by presenting Capt. A. E. Hambelton of the Celtic with a beautifully engraved silver box for cigars and chief-engineer C. C. Lapsley with an electric desk lamp.

As the boat approached Liverpool it was boarded by President John A. F. Aspinall and other prominent members of the Institution of Mechanical Engineers and representatives of the city of Liverpool, who extended a cordial welcome to the visitors, to which Vice-President W. F. M. Goss responded for the Society.

FIRST PROFESSIONAL SESSION

The first regular session of the joint meeting was held Tuesday morning at the Birmingham and Midland Institute. The two societies were welcomed to the city by the Lord Mayor of Birmingham (Alderman W. H. Bowater) who spoke of the importance of Birmingham as an engineering center and of the interest which the visitors would have in the various plants. The Institution of Mechanical Engineers was founded in Birmingham at the old Queen's hotel, then the terminus of the London and Northwestern Railway, and it was doubly appropriate that the first of these meetings should be held in that city.

Mr. George Tangye, a vice-chairman of the Birmingham reception committee and custodian for the city of the Boulton and Watt relics, said it was his privilege to offer for the acceptance of the American visitors a letter dated 1777, signed by James Watt and addressed to Mathew Boulton, his partner, as a memento of their visit to Birmingham. Although he had presented all the relics to the city and was now merely their custodian until such a time as a suitable place should be found for them, he was sure the gift was made with everybody's approval.

This letter was written on both sides of the paper and framed so that the two sides of the sheet can be read. It bears the inscription, "Presented to The American Society of Mechanical Engineers by George Tangye at the Joint Summer Meeting at Birmingham in July 1910."

President Aspinall, in acknowledging the welcome of the Lord Mayor for the Institution of Mechanical Engineers, said it was fitting that the meeting should be held in a city so closely associated with engineering work and tradition. There is a close connection between Boulton and Watt and their American cousins. A few months ago the Americans were celebrating the opening of the Hudson River to steam navigation and Robert Fulton bought his first engine from Boulton and Watt. Therefore Birmingham had played an important part in the development of engineering on both sides of the Atlantic. He reminded the meeting that the first man to spin cotton without the aid of human hands was a Birmingham man, John Watt, who began his experiments in 1730 and in 1741 was entirely successful. In the museum at Birmingham is the first hank of cotton spun by machinery. Engineers recognize how much they owe to Birmingham.

Dr. W. F. M. Goss on behalf of The American Society of Mechanical Engineers said they came joyfully to Old England because many of the practices of their profession had their beginning in Birmingham. Here the implements were made with which many of the pioneers of America furnished their homes, cultivated their ground and equipped their mills. Although Watt and Boulton worked in the highlands of England, they in America shared in the output of their factory. The Society was proud to be the guest of an institution whose first president was George Stephenson. At the present day the engineer had become the world's great civilizer. For the rush light he had given electric illumination and for the stage-coach the express train. He had given men new occupations and in the transforming process the engineers of England and America had each played their part. Only an ocean lay between them and thanks to English shipbuilders this was no longer a barrier, but a means of communication. The maintenance of their respective traditions would doubtless always require separate organizations, but they might readily federate the spirit of the organizations, to which end this meeting would contribute. The joint meeting, the good fellowship which will inevitably come out of it, the pleasure which the Americans as cordially-welcomed guests are to enjoy, were sure to prove contributing factors in the working out of such a result. He expressed the sincere thanks of the Society for the gift of the Watt memorial by Mr. Tangye. Americans had admired the beautiful marble memorial of that great engineer in Westminster Abbey and they would doubly admire a gift which was a fragment of Watt's own work.

Following these formal addresses President Aspinall took the chair and proposed that a cablegram be sent to George Westinghouse expressing the regret of the Institution at his absence. The Secretary read the minutes of the last meeting of the Institution, the election of candidates was announced, and the meeting then proceeded to the discussion of the professional papers which were devoted to the general subject of Handling Locomotives at Terminals. The first paper offered was by Cecil W. Paget, Mem.I.M.E., general superintendent of the Midland Railway, on English Running-Shed Practice, corresponding to American enginehouse practice. The paper described running sheds as built in England, consisting of two types, with the tracks laid parallel and with tracks radiating from a central turntable. The straight sheds are economical in first cost and maintenance, but unless of the type known as "through sheds"

they are awkward to work; while the latter class are draughty. The paper discussed the equipment of running sheds, including shear legs for lifting engines, lighting, arrangements for washing out, water softening, methods of coaling, etc. It then took up running-shed arrangements, and examinations of engines. This paper, in common with the other English papers presented at the joint meetings, has been sent to the membership of the Society.

There were four American papers on this subject as follows: Handling Locomotives at Terminals, by Frederic M. Whyte; Engine House Practice, by F. H. Clark; American Locomotive Terminals, by William Forsyth; and Handling Engines, by H. H. Vaughan. These papers have been published in The Journal, and were presented in abstract at the meeting by F. H. Clark. They dealt systematically with the subject of the meeting, the first discussing briefly the different phases of the whole subject, including the location and layout of a terminal, the organization and method of conducting the work at a terminal and pooling locomotives and crews. Some years ago it was general practice to assign a locomotive to a crew and both crew and locomotive to particular runs. The plan was later developed to increase the service of locomotives by placing any crew on any locomotive instead of holding the locomotive until its assigned crew could obtain the necessary rest.

The paper by Mr. Clark considered in detail terminal design and the handling of locomotives to secure continual operation. Mr. Forsyth described a particular terminal, that of the Pennsylvania Railroad at East Altoona, including the organization of the plant. Mr. Vaughan discussed the question of pooling, concluding that in passenger service it was objectionable, while in freight service it was advisable if conditions were such that engines could not be run with assigned crews.

These papers were discussed by George Hughes, President J. A. F. Aspinall, Jas. M. Dodge, Henry Fowler, H. L. Gantt, A. D. Jones, and Jas. E. Sague. During the discussion the chair was vacated by President Aspinall and taken by Dr. Goss. The discussion upon these and other papers presented at the joint meeting will be published in a later number of The Journal.

THE SECOND PROFESSIONAL SESSION

At the opening of the session on Wednesday President Aspinall announced the receipt of a cablegram from President Westinghouse

in reply to the one sent him, expressing his regret because of his absence from the meetings and the highest hope that the joint meeting would be of permanent value in cementing the relations between the societies and in promoting coöperation between the engineers of the two countries.

Dr. Goss was then asked to take the chair and a paper was read on High-Speed Tools and Machines to Fit Them by H. I. Brackenbury of Newcastle-on-Tyne, Mem.I.M.E. This paper considered the characteristics of high-speed tools and of the steels of which they are made and discussed machine tools for the use of such steel. It compared machine design before and after the introduction of high speed tools and laws regarding the weight and power of machines. There were data on the cost of machining and on the power required for cutting, with numerous excellent examples of rapid production.

Following this a topical discussion was offered by three American members. Mr. John Calder gave examples, illustrated by lantern slides, of rapid production in machine tool work, the data having been contributed by some twenty-five different firms and machine tool builders. It covered subjects of heavy lathe-work, including tire and axle turning, milling, gear cutting, turret-lathe work and grinding.

Mr. Luther D. Burlingame followed with an account, also illustrated by lantern slides, of examples of work done in the shops and on the tools of the Brown & Sharpe Mfg. Company. He showed illustrations of jigs, and tools used with them, to indicate the complexity of modern manufacturing methods. He also gave tables of limits indicating the degree of precision to be attained in grinding for running and force fits.

Mr. L. P. Alford presented a resumé of the most recent accomplishments in heavy drilling by the use of high-speed drills, driven by tools especially designed for rapid production.

Discussion was offered by J. Hartley Wicksteed, William Lodge, Dempster Smith, Walter Carter, Fred. W. Taylor, Frank B. Gilbreth, President Aspinall, and Alexander Taylor (read by the secretary).

The subject of tooth gearing was then considered, a paper first being presented by J. D. Steven of Birmingham, Mem.I.M.E., in which different methods of cutting gear teeth were discussed and different systems of tooth design were compared, with the conclusion that conditions have so radically changed during the past two years that there is every reason to consider the question with an open mind. If a new form of tooth is desirable, he believed that a stub

tooth with 20-deg. pressure angle would be a change in the right direction, because it can be used in its true form down to 12 teeth; it is a stronger form and most commonly used; and a large proportion of its face does useful work.

Mr. Wilfred Lewis, Mem.Am.Soc.M.E., read a paper on Interchangeable Involute Gearing, prepared at the request of the Meetings Committee as a discussion on the subject, but not necessarily expressive of the opinions of the Gear Committee of which he is chairman. He, however, outlined the investigations of the committee up to the present time and gave drawings of the gear testing machine which had been designed for testing gears of different types and which is now being used for the purposes of the committee under the direction of Professor Lanza at the Massachusetts Institute of Technology. The paper illustrated the shapes of teeth to be tested which include teeth of different obliquities. Mr. Lewis advocated a pressure angle of 22½ deg. and an addendum of seven-eighths module.

These two papers were discussed by P. V. Vernon and Luther D. Burlingame; a written discussion contributed by C. R. Gabriel, member of the Gear Committee, and read by Secretary Calvin W. Rice, argued for the Brown & Sharpe 14½-deg. standard, with modified tooth to avoid interference, as the most practical and useful form for present-day conditions.

After this discussion a resolution was offered thanking the hosts and people in and around Birmingham for the hospitality extended to the members of the two Institutions.

ENTERTAINMENT AT BIRMINGHAM

Every convenience was provided at Birmingham, as well as later at London, in the way of provision for mail, telegraph, telephone and messenger-service, offices for the transaction of business, and the leading clubs extended invitations to the visitors to share in the club privileges.

Luncheon was served in the Town Hall at the close of each of the professional sessions.

The chief event during the stay was the garden fête, on Tuesday evening in the Botanical Gardens at Edgbaston, by invitation of the Birmingham reception committee. The grounds were beautifully illuminated with fairy lamps and Japanese lanterns. There were 10,000 of the many-colored little lamps and 1000 Japanese lanterns strung on frame work of bamboo. The conservatories were

used as a place of assembly and for the reception at which the Lord Mayor and Lady Mayoress (Alderman and Mrs. Bowater) and members of the Birmingham reception committee received. Music was furnished by the band of the Royal Marines from Portsmouth and during the evening there was a display of fireworks which closed with a set piece showing the British and American flags crossed. The fête was most picturesque in its settings and an occasion of unusual pleasure to those in attendance.

Numerous excursions were made on Tuesday afternoon to places of interest in the vicinity of Birmingham. Among these was one to the testing-station of the Pump & Power Company at the South Staffordshire Mond Gas (Power and Heating) Company's at Dudley Port, Tipton; the works of the Austin Motor Company; the Metropolitan Amalgamated Railway, Carriage and Wagon Company, Saltley; and the Frankley filter-beds of the Corporation Water Works; while some went to Stratford-upon-Avon, Worcester, Stoneleigh Park, and Kenilworth.

A number took advantage of the invitation of Mr. George Tangye to visit the Watt room at his residence, Heathfield, where are located the Watt relics which are preserved as nearly as possible in the way the famous engineer left them.

On Wednesday afternoon the new buildings of the University of Birmingham were visited. The company was cordially welcomed by the principal, Sir Oliver Lodge and Vice-Chancellor Alderman C. G. Beale. The original buildings of the university are in Birmingham and the new buildings, recently finished and equipped are located outside at Bournbrook on a site of ample area and contain departments for the study of several branches of engineering. The university is of peculiar interest to Americans as it represents the latest developments among English institutions for technical training. The equipment was selected only after an extended study of both American and European universities and is aimed to be evenly balanced in the various departments rather than providing for specializing as in certain of the American schools of engineering.

The concluding event in Birmingham was a reception at the Council House on Wednesday evening, attended by about 1000 guests, at which the Lord Mayor and Lady Mayoress and various city officials received. There was music and a collation; and addresses expressing gratitude to the Lord Mayor and Lady Mayoress were made by President Aspinall and Dr. Goss, thanking them for the extraordinary kindness displayed in the visit of the engineers and their

friends to the city. The Lord Mayor replied, humorously expressing his own gratification that the efforts of the people of Birmingham to entertain their guests had been so much enjoyed.

PROFESSIONAL SESSION AT LONDON

The third professional session was held in the rooms of the Institution of Civil Engineers, London, the subject for discussion being the Electrification of Railways. In the unavoidable absence of Mr. James C. Inglis, president of the Institution, Mr. Alexander Siemens, senior vice-president, welcomed the members of the two Societies.

President Aspinall in replying expressed his gratification that the meeting could be held in the present building of the institution, because a new building was shortly to be erected and when their American friends paid their next visit to England they would be able to inspect the new home of that institution. Dr. Goss also fittingly responded.

Of the papers presented, that by George Westinghouse on the Electrification of Railways compared the present status of electrification to the conditions existing some years ago in this country when railroads used different gages of track, preventing interchange of rolling stock and the operation of through trains. Different roads are now employing different systems of current supply in their electrification projects which will eventually interfer with the transfer of traffic from one road to another. The author called attention to the danger of this practice and pleaded for the adoption of a uniform system before electrification is extended far enough to bring about the difficulties mentioned. In this connection he summarized by the use of tables, diagrams and photographs the advantages and disadvantages of the direct current, three-phase and single-phase systems and outlined the operating experiences of various railroads, both in this country and abroad, with the use of these systems.

W. B. Potter, Mem.Am.Soc.M.E., discussed in his paper on Economics of Railway Electrification the commercial and economic considerations governing the electrification of railways, outlined the relative advantages of steam and electricity and considered the conditions of operation with various requirements of service as affecting the problem. He believed that the use of the 1200-volt direct-current system for interurban railroads will greatly increase and anticipated the entire discontinuance of the single-phase system.

The Electrification of Trunk Lines, by L. R. Pomeroy, Mem. Am.Soc.M.E., discussed this subject from a commercial standpoint and contained calculations as to the relative cost of steam and electric operation. Examples were worked out in detail for specific cases.

The Electrification of Suburban Railways by F. W. Carter, Mem. I.M.E., discussed the present and future of electrification in England, with particular attention to the conditions affecting suburban service. The author saw little prospect of general electrification in England, as no advantage is apparent which would justify the expense. Only in the case of heavy suburban service is there any commercial advantage accruing from electrification.

H. M. Hobart, Mem.I.M.E., in his paper on The Cost of Electrically-Propelled Suburban Trains, treated in considerable detail the various factors which enter into the cost of electric suburban service and their influence on the choice of a system of current supply.

These papers were discussed by H. F. Parshall, J. Dalziel, Sidney Stone, Charles F. Scott, H. M. Hobart, Angus Sinclair, J. G. Wilson, F. R. Hutton, F. W. Carter, H. H. Barnes and President Aspinall.

ENTERTAINMENT IN LONDON

The whole day Thursday was devoted to excursions, three trips being provided for. The first of these was to Coventry and Rugby with an opportunity to visit the Daimler works and the plants of Alfred Herbert, Willans and Robinson, and the British Thompson Houston Co. Most of the ladies went to Kenilworth, Warwick, and Stratford-upon-Avon. The other excursion was to Litchfield.

Thurdsay evening there was a conversazione at the Institution House at Storey's-gate, St. James Park, Westminster. President and Mrs. Aspinall received and a brief lecture was given by Dr. Hele-Shaw on the subject of the Stability of Aeroplanes and the Theory of Stream Lines, which was illustrated by lantern slides having glycerine forced between glass plates, giving a most beautiful effect.

On Friday afternoon there were garden fêtes given by Wm. H. Maw, past-president, and Mrs. Maw, and Sir John Thornycroft, member of the council, and Lady Thornycroft. Visits were also arranged for those who cared to go to the museum of the Public Record Office and to the Times Office.

On Saturday, two excursions were arranged taking the entire day, both covering the same ground but in different directions. These were to Windsor and Marlow. Part of the trip was by special train and part by launches on the Thames. All had an opportunity to visit Windsor Castle under the guidance of the Mayor of Windsor, Councillor C. F. Dyson and several members of the Institution. Luncheon and tea were served and the trips were regarded by many as the most beautiful of the whole meeting.

In the evening there was an opportunity for a visit to the Japan-British exhibition at Shepards Bush and to the Garden Club.

On Sunday afternoon a visit was made to the Zoological Gardens in Regents Park and in the evening a company assembled at Westminster Abbey to inspect the Baker Memorial Window and later to attend the service in the Nave, places being reserved for the visitors.

The members of the Society were especially interested in the window because the Society had contributed towards the erection of this memorial to the memory of a man who possessed such remarkable engineering ability. It is the first time in Europe that a full and satisfactory recognition of the execution of engineering work has been so appropriately honored.

THE INSTITUTION DINNER

The social functions of the joint meeting were brought to a close on Friday evening in the Connaught Rooms. The loyal toasts having been drunk with enthusiasm, Mr. Aspinall gave The Health of the President of the United States and Ambassador Reid responding, said that he was there to recognize the peculiar fitness of a toast to the President of the United States from the great profession which had wrought these marvelous advances of our modern life, and was still carrying on the high tradition of its earlier years.

Sir William White, proposing The American Society of Mechanical Engineers recalled the fact that it was founded but thirty years ago and now it had a membership of about four thousand. The English Institution was founded in 1847. With common objects and common ideals, with a common desire to do their duty in the cause of humanity, they, as the years rolled on, were being drawn closer together, both furthering the cause of civilization and all that made for the good of humanity, and bringing the nations together in happiness, brotherhood and peace. In the maintenance of law

and order, and the repression of rebellion and wrong, the mechanical engineer bore a prominent part, and the cause of liberty and truth owed much to him.

In acknowledging the toast, Professor Hutton, honorary secretary of the Society, asserted amid general applause, that Americans honored King Edward, and with Englishmen mourned his death, because they recognized in him a man, self-sacrificing and self-immolating, when by immolating himself, he could advance the interests of his great Empire. The present gathering was one of more than merely good friends. It had an inner and broader significance. It was the culmination of a series of meetings of the mechanical engineers from both sides of the Atlantic, and mechanical engineers were potent factors which underlay the civilization of the Anglo-Saxon race. The American was so much at home in the United Kindgom, because he and his host had a common ideal. As long as they had that ideal their civilization rested on a bed-rock so massive that there was no force which could ever shake the nations apart.

Our Other Guest was given by Mr. Edward B. Ellington, vice-president of the Institution and replied to by Dr. Glacebrook. Success to the Institution was proposed by Dr. Goss, and acknowledged by the president.

A NOTE OF COMMENT

Of the entertainment provided the American engineers, it can only be said that the Americans were literally overwhelmed with the courtesies extended with the preparation made for their pleasure. Collations, luncheons or teas, were served on every occasion and there was arrangement even to the extent of cab and omnibus conveyance. Not only were the excursions for members and guests conducted on most liberal plans, but the ladies' committee provided a special program of most entertaining visits and various other functions that added much to the delight of the lady guests.

A word should be said about the printed matter supplied by the Institution. A program of over thirty closely-printed pages was issued, filled with information most likely to be desired by the visitors, together with a series of finely executed maps of the principal places to be visited with the points of interest and the places where members were to assemble specially indicated. A souvenir was issued by President Aspinall as a memento of the joint meeting contain-

ing beautifully executed portraits of the presidents of the two societies of Stevenson, Boulton, Watt, Trevithick, Fulton and Symington. There were interesting anecdotes and quaint illustrations relating to early events in engineering compiled from various sources, together with a photograph of the first hank of cotton spun by John Wyatt.

A VOTE OF THANKS

At the conclusion of the last professional session a vote of thanks was given by the members of The American Society of Mechanical Engineers, the text of which follows:

The American Society of Mechanical Engineers, present by invitation at the closing session of the joint summer meeting of 1910 with the Institution of Mechanical Engineers asks permission to offer for record the following minute and requests its acting president to put the resolution to vote:

The American Society of Mechanical Engineers has been enveloped in an atmosphere of courteous, friendly and devoted attention from the moment that the vessel which carried the official and organized party entered the River Mercy at Liverpool. Beginning with the reception on the steamer, at which the president and secretary of the Institution officially welcomed the party, in conjunction with representatives of the city and other interests of that progressive corporation, and continued through the arrangements for comfortable and convenient transportation by train to the place of first meeting, providing on arrival for ample and satisfactory hotel accommodations and for organizing in a masterly way, which extended even to the most minute detail for the enjoyment of the visitors, in affording opportunities to visit works over the city, for transportation, and for motor drives in the historic midlands of England, the Institution of Mechanical Engineers has placed The American Society of Mechanical Engineers under an obligation which no mere words or resolutions are an adequate medium to discharge. The visitors can only assure the home Society, its president, its council, its secretary and its organizing committee, that just because they are themselves organizers and doers, they are able most thoroughly to appreciate such work well done.

The American Society also appreciates most sincerely the generous purpose which has spared no sacrifice when the desired object of the hosts has had to be met by the ordinary commercial procedure as respect outside parties. Hence, the Society moves and seconds the following resolution:

Resolved: That The American Society of Mechanical Engineers desires, in addition to the resolutions passed in Birmingham thanking those who had put both bodies under a pleasing debt of obligation, to put on record certain special resolutions of thanks.

Resolved: That The American Society thanks the Institution of Mechanical Engineers, its president, council, secretary and committee for their ceaseless, unremitting and painstaking labor for the pleasure and success of the joint meeting of 1910 in Birmingham and London.

Resolved: That this joint meeting will be a memory of delight and pleasure for all the Americans who have been privileged to share in it.

Resolved: That The American Society of Mechanical Engineers desires to thank the Birmingham Reception Committee for certain special considerations at their hands which were extended exclusively to the American membeis of the joint party and requests the Institution to be the channel for conveying such action of thanks.

Resolved: That The American Society of Mechanical Engineers desires by this action to express for the ladies who have accompanied the members something of the appreciation of both members and ladies for the delicate and considerate attention which has made their participation a delight and a possibility; and the members feel that any international friendships springing from these days of close association are sure to last forward into happy future years.

Resolved: That The American Society of Mechanical Engineers requests the Institution of Mechanical Engineers to incorporate this minute and action as part of it record of the the proceedings of the joint summer meeting of 1910.

MEETING OF THE A. I. M. E. IN THE CANAL ZONE

The members of this Society have been invited to join with the American Institute of Mining Engineers during their visit to the Canal Zone, October 21 to November 15, so far as accommodations will permit. The party sails from New York on October 21 on the Hamburg-American liner Prinz August Wilhelm, touching at Havana and Kingston en route to Colon. A full week will be spent in the the Canal Zone, during which time the party will inspect the work on the canal in addition to holding professional sessions. The cost of the trip, including berth and meals on the steamer, railroad transportation, meals and accommodations at the Hotel Tivoli in the Canal Zone, will be $200. This rate holds good until September 20, after which an additional charge of $50 will be made by the steamship company. Further details regarding the arrangements for the trip may be obtained from Dr. Joseph Struthers, Assistant Secretary of the Institute.

NECROLOGY

JOHN DENISON EVARTS DUNCAN

John Denison Evarts Duncan, Life Member of the Society, was born at Union Falls, N. Y., July 26, 1871. His preparations for his university course was in the high school of Ann Arbor, Mich., and in 1893 he was graduated from the University of Michigan with the degree of B.S. in electrical engineering and in 1894 from Cornell University with the degree of M.E. From 1894 to 1896 Mr. Duncan was employed by the Terre Haute Street Railway Company, Terre Haute, Ind., and the Stanley Electric Manufacturing Company, Pittsfield, Mass. With the latter company he was associated with Mr. Stanley and Mr. Chesney in their extensive experimental work connected with the solving of the early high tension problems which were first studied and worked out at their factory. On leaving the Stanley Electric Manufacturing Company, Mr. Duncan successively held positions in New York with the Metropolitan Street Railway Company; the Western Electric Company; the New York Telephone Company; Westinghouse, Church, Kerr and Company; and the Consolidated Railway Electric Lighting and Equipment Company. In 1901 Mr. Duncan entered the employ of Sanderson and Porter, 52 William Street, New York, and in 1903 was sent to Portsmouth, N. H., by his firm to construct a 1000-kilowatt power station for the Rockingham County Light and Power Company. At the time of his death, July 13, 1910, he held the position of managing engineer with the same firm. While directing the engineering work of this firm Mr. Duncan was in responsible charge of the design and execution of many large and diversified projects and well earned the high esteem and confidence of his employers, associates and friends in engineering and business circles. All who knew him and his work recognized his versatility, sound judgment and exceptional ability.

Mr. Duncan was a member of the American Institute of Electrical Engineers, the Brooklyn Engineers Club, the Engineers Club of New York, the Machinery Club of the City of New York, the Michigan Club of New York, the University of Michigan Club, and the Cornell University Club of New York.

JAMES B. FAULKS, JR.

James B. Faulks, Jr., was born December 13, 1873, at East Orange, N. J. After his early education in the public schools, he attended the Bordentown Military Institute and later entered Stevens Institute of Technology from which he was graduated in 1896 with the degree of M.E. He held during his lifetime many positions of prominence in engineering work, among which may be mentioned that of draftsman with the Standard Air Brake Company, of engineer of tests with the Edison Electric Illuminating Company, of designer with the Harrisburg Foundry and Machine Works and also with the Crocker-Wheeler Company and of mechanical engineer with the New York Safety Steam Power Company. He was also prominent in connection with experimental work on the Roumaine Cultivator, and was identified with research work in gas engines. In 1904 Mr. Faulks accepted a position at Syracuse University as an instructor in the L. C. Smith College of Applied Science, and at the time of his death, July 14, 1910, was professor of experimental engineering in the same college.

Professor Faulks was a Junior Member of the Society and also a member of the Technology Club of Syracuse.

WILLIAM W. SNOW

William W. Snow who died at his home in Hillburn, N. Y., April 26, 1910, was born at Heath, Franklin County, Mass., July 17, 1828. At fifteen years of age he took up the book-binding trade, but at the end of three years left it to become assistant civil engineer with the Worcester and Nashua Railroad. In 1848 he went to Woonsocket, R. I., and for the five succeeding years was employed in the foundry at that place, when he accepted a position as superintendent of the Indianapolis City Foundry. In 1856 he established a factory at Newburgh, N. Y., for the manufacture of car wheels. This business was successfully carried on under the general management of Mr. Snow until 1859, when he withdrew his interests to become general manager of the Union Car Wheel Works, Jersey City, N. J. In 1866 Mr. Snow came to Ramapo, N. Y., and with others organized the Ramapo Wheel and Foundry Company, of which he was made general manager and superintendent and finally president. In 1881 he organized the Ramapo Iron Works in Hillburn, N. Y., a village founded by himself. Nine years later he began the erection of commodious buildings in Mahwah and installed therein the Ramapo

Iron Foundry Company. He was the president of this company until its consolidation with the American Brake Shoe and Foundry Company when he became chairman of its Executive Board, which position he held at his death.

In 1895 Mr. Snow was appointed by Governor Morton one of the New York State commissioners to the Atlanta, Ga., Exposition. He joined this Society in 1889 and was also a member of clubs in Boston Philadelphia and Chicago. He was well known in European circles as one of the most prominent manufacturers of this country.

WILLIAM E. CRANE

William E. Crance died on May 22, at Duluth, Minn., after a short illness. He was born in Burlington, Conn., and received his early education at the local schools. At fourteen years of age he began to apply himself to engineering and two years later took charge of a small engine at Bristol, Conn. He later went to Waterbury where for twenty-five years he was connected with the Benedict and Burnham Company as chief engineer. After severing his connection with this firm he became consulting engineer for the New England Engineering Company and designed several power plants of considerable importance, notably, that of the Kings County Electric Light and Power Company, the Passaic Electric Light and Power Company and the Albany and Hudson Railway Company. Later he was chief engineer at the Hotel Astor in New York City, but failing health forced him to resign and seek the climate of Minnesota.

Mr. Crane was a member of the National Association of Steam Engineers as well as of this Society, which he joined in 1887. He was the author of a treatise on American Stationary Engineering and had the distinction of being the first man to use the double eccentric on a Corliss engine. In addition to his engineering activities he took a keen interest in public affairs and contributed much to the press on social conditions.

THE STRENGTH OF CAST-IRON PUNCH AND RIVETER FRAMES

By Prof. A. L. Jenkins, Published in the Journal for May 1910

ABSTRACT OF PAPER

A brief résumé is given of the important theories proposed for the analysis of stresses in straight cast-iron beams. The examination of the various formulae proposed for curved beams shows that certain assumptions made in their derivations are not true for cast iron. Tests on small castings, similar in shape to punch frames, failed to verify any given formula. The relation between the strength of frames and the test bars cast with them is approximately represented by the ordinary formula for straight beams subjected to combined bending and tension. A criticism of the Résal and Pearson-Andrews formulae states that they are not true for cast iron, are unwieldy in their application and involve considerable chance of error. Some of the castings failed in a very peculiar manner, and under a load much smaller than that predicted by the formulae, which suggests the advisability of investigating such machine parts by a different method. The writer claims that calculations based on the load-deflection curve drawn by an autographic recorder on a testing machine are of no value.

DISCUSSION

James Christie. The experiments of Professor Jenkins show the existence of serious stresses at the junction of thick and thin sections of the castings. This accounts for the failure of specimens Nos. 4, 5 and 12 at test loads one-third less than for specimens Nos. 6 and 14, whereas the estimated resistance of the latter, due to increased web thickness, is only 10 per cent greater than the former. Fairbairn and Hodgkinson observed this fact in their experiments during the middle of the past century, and aimed to obviate it by gradually tapering the thick into the thin sections, a practice of experienced designers today. Indeed, the same lines of weakness have been observed in rolled sections, illustrated in the tests of rolled I-beams by Professor Marburg.[1]

2 It is generally believed that these internal stresses are relieved by molecular adjustment in course of time. The author does not in-

[1]Vol. IX, Proceedings of the American Society for Testing Materials.

form us what time elapsed between the casting and testing of his specimens. If the time was quite brief, satisfactory results could not be expected from the tests.

3 The writer desires to direct attention to what he believes to be a secondary stress occurring in the frames of tools of this class, and if the views hereafter stated are incorrect, desires to be corrected.

4 In clamps shaped like *A* in Fig. 1 it has been observed that when the back of the clamp is weak as compared with the arms, the back deflects inward when the clamp is subjected to a distending force at the ends of the arms, making the piece assume the shape *B*. A similar tendency has been noticed in punching machines with a weak back or spine, indicating that the flexure inward of the beam

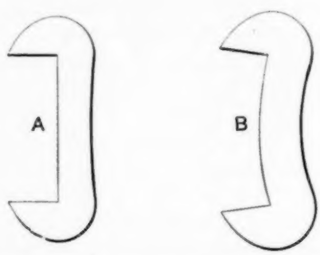


FIG. 1 DEFORMATION OF CLAMP UNDER STRESS

forming the spine of the frame arises from the distending force applied at the outer end of the arms. This force acts through lever arms whose length can be taken as the distance from the neutral axis or center of gravity of the spine to the end where the force is applied and is resisted by the beam of the spine whose length may be taken as the distance between the neutral axes at the junction of the arms and the spine, or resisting lever arms half the length of this beam.

5 This inward-acting transverse stress can be directly resolved into its resultant flange stresses. The resultant tension on the inner flange is believed by the writer to be independent of and supplementary to the tension of the same flange resulting from the direct action of the applied stress acting through the lever arms of the frame.

6 Let us test this assumption by applying it to the author's specimens Nos. 6 and 14 with the web 0.93 in. thick. From a practical point of view, in computation it is unnecessary to resort to the tedious process of calculating the flexural moments of the section, with all the doubts involved, especially when considering unsymmet-

rical sections of cast iron. By adding one-sixth of the web area to the flanges we can deal with the latter alone and proceed by the simple and direct law of the lever. When considering rupture in cast-iron beams, tension flange alone can be regarded, as rupture usually starts in the tension flange, irrespective of the magnitude of the compression flange.

7 It is good practice to assume the ultimate tensile strength of ordinary cast iron at from 15,000 to 18,000 lb. per sq. in. according to the thickness of the metal, and in consideration of the unequal distribution of stress through beam flanges. For specimens Nos. 6 and 14 the average unit resistance of the tension flange is assumed to be 18,000 lb. per sq. in. of section, the effective flange area is 3.54 sq. in. and total flange resistance 63,720 lb. The positive lever arm from the point where the stress is applied to the center of the back flange is 12.55 in. and the resisting lever arm or distance between inner and outer flange centers is 4.25 in. Calling the testing stress applied X, $\frac{12.55\,X}{4.25} = 2.95\,X =$ the stress on the inner or tension flange resulting from this source alone.

8 Considering the secondary stresses, the positive lever arm as heretofore denoted would be 9.5 in. long, and the effective beam length of the spine would be about 6.5 in. long. From these we have $\frac{9.5\,X}{3.25} \times 2 = 5.85\,X =$ the transverse stress acting inwards on the spine. Resolving this as before by simple leverage gives $\frac{2.92\,X \times 3.25}{4.25} = 2.23\,X$ as the resulting secondary tension on the inner flange. Hence, $2.95\,X + 2.23\,X = 5.18\,X =$ total tension in the flange or $X = \frac{63720}{5.18} = 12{,}300$ lb., which agrees closely with the ultimate test load obtained by the author on specimens Nos. 6 and 14.

9 Referring to Fig. 1 of the paper, specimens Nos. 1, 2 and 3, whose back or spine are rectangular in section, 4 in. by 2.5 in., assume this to be modified into a flanged section, for simplicity of computation only. It can be shown that the ultimate transverse strength of a cast-iron beam of rectangular section is identical with that of an equal flanged section of the same depth and sectional area, when the flange widths are about seven-eighths of the depth of the beam and the web

a minimum. This modification gives a tension flange, $3.5 \times 1.43 = 5$ sq. in., and 2.57 in. between centers of flanges, which is the resisting lever arm. The positive lever arm by the figure becomes 10.28 in. long and we have as before $\frac{10.28\ X}{2.57} = 4\ X$ = tension on the inner flange of spine from this source. The inward-acting transverse stress on the spine, obtained as in the previous instance, would be $\frac{9\ X}{3.5} \times 2 = 5.1\ X$, and the resulting secondary tension on the interior flange would be $\frac{2.55\ X + 3.5}{2.57} = 3.5\ X$, and the total tension on the flange $= 4\ X + 3.5\ X = 7.5\ X$. But the maximum tensile strength of the flange of 5-sq. in. area (assuming the unit stress at 17,000 lb. per sq. in.) = 85,000 lb., therefore X = 11,300 lb., which compares closely with the actual results of the tests for specimens Nos. 1, 2 and 3.

10 It would have added to the interest of the test, if the author had recorded the deflection of his specimens under various loads, for while the compresssion flange has little significance in offering resistance to rupture, yet it probably excercises an important influence in resisting deflection, a feature entirely ignored by Fairbairn and Hodgkinson when recommending their well-known type of beam, although this influence was previously recognized by Tredgold.

Prof. Walter Rautenstrauch. I was much surprised to find that Professor Jenkins' experiments with cast-iron frames of the C form had led him to the conclusion that the Andrews and Pearson formula gave results which were absurd when compared with those obtained by experiment. That the analysis should be so very incorrect when applied to cast iron was quite contrary to the opinion I had held after my experiments with hooks of wrought iron and cast steel, the results of which are reported in the American Machinist, October 7, 1909.

2 The table of breaking loads and maximum stress at breaking load, a quantity I have never been able to compute by any standard formula, was interesting but not at all adapted to throw any light on the subject of the relation between load and maximum intensity of

stress in cast-iron frames of this sort. In order that I might learn the true state of affairs at first hand, I had a few castings prepared similar to the one shown in Fig. 1 of Professor Jenkins' paper, and tested them. The results of these tests follow.

3 Four castings with dimensions as shown in Fig. 1 were prepared, two by the Isaac G. Johnson Company and two by another firm. The latter two were found to be very defective, being full of blow holes and imperfections which made the results of tests on them of no value. The C castings were tested in a Riehle 100,000-lb. testing machine, and the separation of the points A and B were read by a micrometer caliper to ten-thousandths of an inch. Loads and readings were taken, as shown in Table 1. Casting No. 1 broke as shown in Fig. 1. The relation between load and opening is shown in Fig. 2.

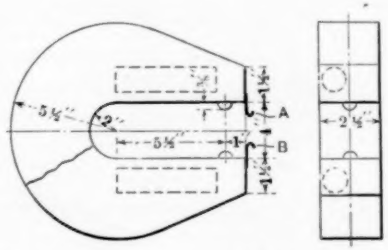


Fig. 1 Dimensions of Test Specimens

4 In tests on casting No. 2 (Table 2) the piece broke in the same manner as casting No. 1 and as shown in Fig. 1. Fig. 3 shows graphically the rate of opening with increase of load.

5 Tension-test specimens and compression-test specimens of standard form were cut from each casting, as shown by dotted lines in Fig. 1, and tested in an Emery hydraulic testing machine of 200,000-lb. capacity (Tables 4 and 5). The results are plotted in Fig. 4 and Fig. 5. The compression specimen from casting No. 1 was ruined and could not be used. The results of the tests on the specimen from casting No. 2 are shown in Table 3 and Fig. 5.

6 From the dimensions of the principal cross section of castings Nos. 1 and 2, as shown in Fig. 1, the functions γ_1 and γ_2 of the Andrews and Pearson formula were computed graphically and checked by analytical methods, giving $\gamma_1 = 1.126$, $\gamma_2 = 0.119$. The radius of curvature of the belly of the casting was found to be $r = 3.75$ in.

The distance from the point of application of the load to the center of gravity of the principal cross section was found to be $L = 9.3$ in.

TABLE 1 TESTS ON CASTING NO. 1

Load	Caliper Reading	Total Opening	Load	Caliper Reading	Total Opening
0	......	......	10500	0.3420	0.0799
500	0.2621	......	11000	0.3468	0.0847
1000	0.2642	0.0021	11500	0.3515	0.0894
1500	0.2675	0.0054	12000	0.3567	0.0946
2000	0.2712	0.0091	12500	0.3617	0.0996
2500	0.2745	0.0124	13000	0.3702	0.1081
3000	0.2783	0.0162	13500	0.3738	0.1117
3500	0.2824	0.0203	14000	0.3772	0.1151
4010	0.2862	0.0241	14500	0.3822	0.1201
4500	0.2891	0.0270	15000	0.3878	0.1256
5000	0.2944	0.0323	15500	0.3942	0.1321
5500	0.2988	0.0367	16000	0.4000	0.1379
6000	0.3025	0.0404	16500	0.4050	0.1429
6500	0.3068	0.0447	17000	0.4102	0 1481
7000	0.3110	0.0489	17500	0.4172	0 1551
7500	0.3153	0.0532	18000	0.4228	0 1607
8000	0.3200	0.0579	18500	0.4298	0.1677
8500	0.3242	0.0621	19000	0.4354	0.1733
9010	0.3282	0.0661	19500	0.4432	0.1811
9500	0.3329	0.0708	20000	0.4493	0.1872
10000	0.3380	0.0759	20500	0.4569	0.1948
			21000	Broke	

TABLE 2 TESTS ON CASTING NO. 2

Load	Caliper Reading	Total Opening	Load	Caliper Reading	Total Opening
0	.....	.....	11070	0.3795	0.0844
500	0.2951	.....	12000	0.3885	0.0934
1080	0.2981	0.0030	13020	0.3992	0.1041
2040	0.3050	0.0099	14010	0.4079	0.1146
2930	0.3123	0.0172	14970	0.4207	0.1256
4030	0.3202	0.0251	15770	0.4300	0.1349
5050	0.3279	0.0328	16810	0.4417	0.1466
7040	0.3450	0.0499	18010	0.4548	0.1597
8030	0.3533	0.0582	18980	0.4677	0.1726
9000	0.3611	0.0660	20000	Broke	......
10030	0.3709	0.0758			

The distance from the center of gravity to the point most strained in tension was found to be $c = 1.8$ in. The area of the section was 9 sq. in. The moment of inertia of the section about the gravity axis was 9.72 biquad. in. The modulus of elasticity in compression was

TABLE 3 COMPRESSION TEST ON CASTING NO. 2

DIAMETER OF SPECIMEN = 1 IN.

Actual Load	Load per sq. in.	Total Compres.	Actual Load	Load per sq. in.	Total Compres.
0	....	....	8000	10200	0.00120
500	637	0.00005	9000	11460	0.00140
1000	1273	0.00010	10000	12720	0.00160
1500	1910	0.00015	15000	19100	0.00280
2000	2550	0.00015	20000	25440	0.00380
2500	3180	0.00020	25000	31800	0.00510
3000	3820	0.00020	30000	38200	0.00690
3500	4460	0.00035	35000	44600	0.00900
4000	5100	0.00035	40000	51000	0.01200
5000	6360	0.00055	45000	57400	0.01500
6000	7650	0.00070	50000	63600	0.22000
7000	8900	0.00090	89800	114600	Failure

TABLE 4 TENSION TEST ON CASTING NO. 2

DIAMETER OF SPECIMEN = 0.503 IN.

Actual Load	Load per sq. in.	Total Extension	Actual Load	Load per sq. in.	Total Extension
0	0	0.00000	3000	15000	0.00350
500	2500	0.00045	3500	17500	0.00450
1000	5000	0.00100	4000	20000	0.00570
1500	7500	0.00155	4500	22500	0.00720
2000	10000	0.00210	5000	25000	0.01130
2500	12500	0.00270			**Failure**

TABLE 5 TENSION TEST ON CASTING NO. 1

DIAMETER OF SPECIMEN = 0.506 IN.

Actual Load	Load per sq. in.	Total Extension	Actual Load	Load per sq. in.	Total Extension
0	....	....	2500	12500	0.00225
500	2500	0.00030	3000	15000	0.00305
1500	5000	0.00060	3500	17500	0.00420
1500	7500	0.00095	4000	20000	
2000	10000	0.00165			

Grips slipped at 4000lb. and the experiment was discontinued.

about 14,600,000 and the modulus of elasticity computed from the readings of the extensometer about 9,000,000 in the first case and about 6,000,000 in the second case.

7 The extensometer used, which was one devised by the officers in the materials testing laboratory of Columbia University, is considered more adaptable to measuring changes in the rate of stretch with load than the exact stretch at any particular load. This is especially true with short specimens such as were used in these tests. For this reason it is assumed that the modulus in compression and tension are approximately equal, although it cannot be proved by these tests.

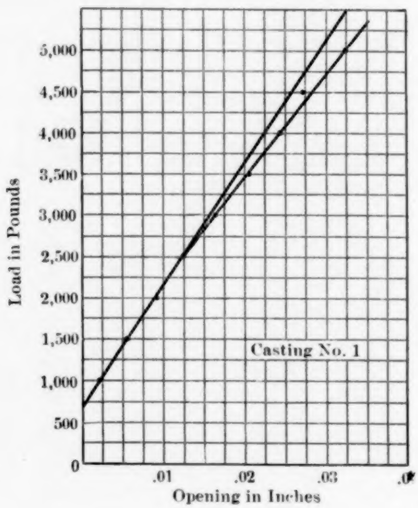


Fig. 2 Rate of Opening with Increase of Load

8 For frames of these proportions, on the basis that the stress in the material is proportional to the strain and that the modulus of elasticity in tension is identical with the modulus of elasticity in compression, and assuming $n = \frac{1}{4}$, the analysis of Andrews and Pearson results in the following formulation:

$$S = \frac{W}{A}\left[\frac{L}{r\gamma_2}\left\{\frac{1}{\left(-\frac{e}{r}\right)^{\frac{3}{4}}} - \gamma_1\right\} + 1\right]$$

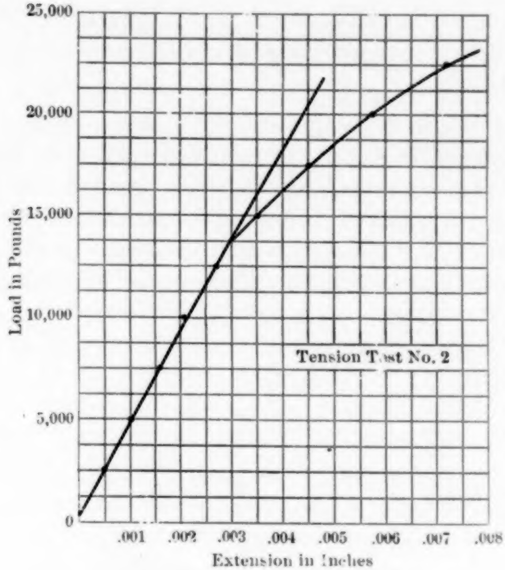


Fig. 4 Stress-Strain Diagram

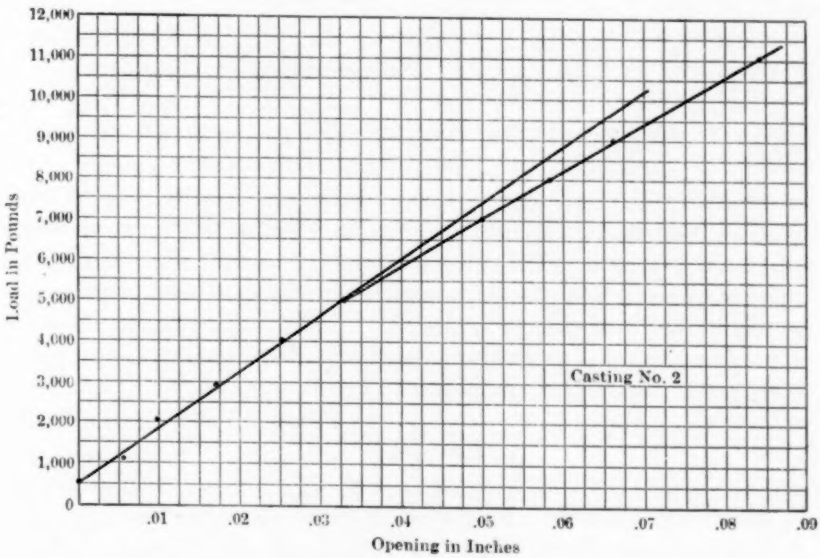
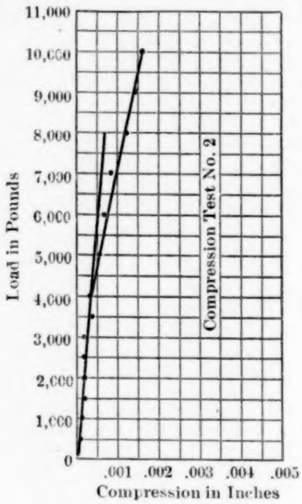


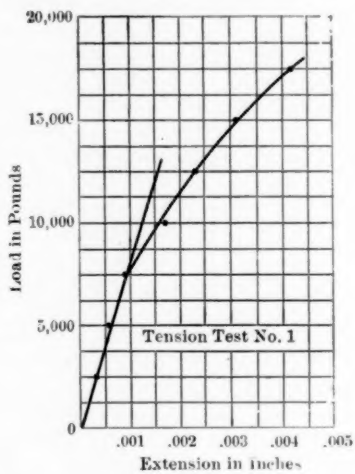
Fig. 3 Rate of Opening with Increase of Load

where the notation is the same as that employed by Professor Jenkins. Substituting the values applicable to these castings, it is found that

$$S = 2.035\, W$$

Upon inspection of Fig. 2 it will be noted that casting No. 1 begins to change its rate of opening at some load between 2500 and 2750 lb. and accordingly the rate of stretch with load on the tensile test specimen is predicted to change at a load between 7100 lb. and 7800 lb. per sq. in. Reference to Fig. 6 will show that the change in the rate





Figs. 5 and 6 Stress-Strain Diagrams

of stretch with load when the specimen was tested in tension took place at 7500 lb. per sq. in. Casting No. 2 begins to change at about 14,150 lb. per sq. in. Referring to Fig. 5 it is seen that the change in the rate of stretch in the specimen when tested in tension takes place at about 13,750 lb. per sq. in.

9 According to the formula usually applied to such cases the following results would be expected

$$S = \frac{Mc}{I} + \frac{W}{A}$$

in which the symbols are as used by Professor Jenkins. For the particular dimensions of these castings the formula may be written

$$S = 1.834\, W$$

For casting No. 1 this formula would indicate that for a tensile stress of 7500 lb. per sq. in. a load of 4100 lb. would be required, while for casting No. 2 in order that the tensile stress reach 13,750 lb. a load of 7500 lb. would be required. A comparison of the results of these analyses wtih the experimental results is sufficient proof of the accuracy of the Andrews and Pearson formula.

10 In criticism of Professor Jenkins' paper it is noted that the statement made in Par. 13 that the results of the stress predicted by the Andrews and Pearson formula is absurd, is unjust and misleading. The formula is not intended to be used to compute stresses up to the breaking point of the material and such an application of the formula is proof of nothing. That Professor Jenkins found the rate of opening of the frames with load practically constant as stated in Par. 29 is evidence of the fact that the method employed in determining the openings at different loads was not sufficiently refined. In conducting experiments of this sort great accuracy and refinement must be used with either wrought-iron and cast-iron specimens or no results need be expected.

11 In regard to the statement made in Par. 5 relating to the value of Poisson's ratio, it will be found that a change in this ratio from 0.25 to 0.30 will not affect the result more than 3 per cent.

12 Because of the results of these few experiments and in view of the fact that Professor Jenkins' method of experimentation and analysis was not adapted to proving any theory of stress-strain relations, it is believed that the case against the Andrews and Pearson formula is not proved.

13 In conclusion, attention is called to the fact that the uncertain nature of cast iron and the impossibility of determining the effect of shrinkage stresses and imperfections in the casting involve a considerable element of doubt as to the proper working stress to be allowed, no matter what analysis of stress-strain relations is used. But these uncertainties do not justify the application of inaccurate formulae for the determination of the relation between load and maximum intensity of stress. In fact a more accurate analysis of the case as seems to be given by the Andrews and Pearson formula tends to lessen the elements of uncertainty.

Frank I. Ellis. I have always felt, as have my associates who have had considerable experience on this line of work, that the relation of the ultimate strength of a curved cast-iron specimen to that of an attached test bar is a very difficult one to determine. We do

not think anything can be gained by making sample curved sections such as carried out by the author of the paper, unless they are made full size. We have found that in comparing different-sized machines, for instance, one with a housing weighing approximately 9000 lb. against one with a housing weighing 40,000 lb., the relative values as compared with a test bar are not at all the same. We have made no special tests for several years, but carry out all our designing very much on the lines of the conclusion Professor Jenkins came to, that is, design the member from the formula given in those conclusions and then correct to suit our experience. In other words, we figure as closely as possible and then make a further allowance. We commonly use 2500 lb. and sometimes 2000 lb. per sq. in. as a safe value for cast iron for the tension side of all shear housings. On other work we run up in some cases as high as 4500 lb., but in such machines as vertical shears, we would not think of using anything higher than 2500 lb.

2 The paper is a very interesting one, but it has not brought out any new facts in relation to this subject.

Henry Hess. The real question at issue is not one of formulae at all. What should be considered is the yield point; in other words, the elastic limit. The real trouble is that the elastic limit of the material is seldom accurately known. There is now in existence a testing apparatus, probably not familiar to many, which makes it possible to recognize the absolute elastic limit of any structure in any material. This instrument is based on a law which is fairly well recognized, but only recently embodied in practical instruments. This law states that deformation is accompanied by a rise in temperature and that such rise is very marked at the point of change of proportionality between stress and deformation. The instrument consists of a delicate pyrometer and a sensitive gold-leaf galvanometer and shows a sharp break in the recorded line when the elastic limit is reached. If the line starts at an inclination of 45 deg. the change in direction at the elastic limit is not gradual, but is an absolutely definite break to an inclination of say 30 deg. This eliminates all doubt as to the exact value of the elastic limit. The small pyrometer may be clamped in any convenient way to any portion of such structure.

2 The ordinary formulae will apply when there is substituted for the element of inaccuracy, the value of the material constant, absolutely definite knowledge of its value.

Oberlin Smith. In Fig. 1 herewith, which represents the outlines of a typical C-shaped beam such as is used in many forms of press frames, AA is the ram axis along which the pressure acts to force the ends of the beam apart and NN is the neutral axis. My usual practice has been to make the depth of the beam at DD, $D'D'$, and $D''D''$ such as to give equal strength on the line AA when calculated by the cantilever beam formula, with LL and $L'L'$ and $L''L''$ as the respective beam lengths. The breadth of these sub-beams, as they might be called, if uniform would be represented by BB in Fig. 2 or Fig. 3 and the formula would of course depend upon the shape of the cross section. If I am in error in this treatment of the subject I

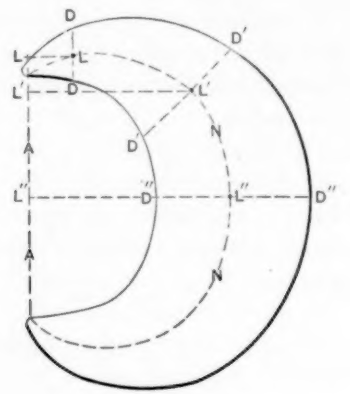


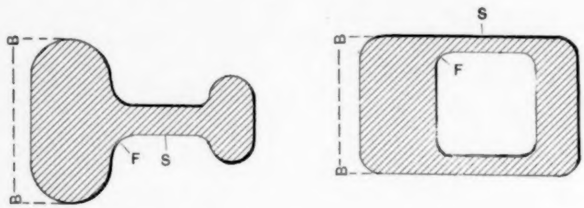
Fig. 1 Typical C-Shaped Beam

should be very glad to hear from others who have made a closer study of the matter.

2 There is a tendency in a beam of this kind for the web to split longitudinally, approximately on the neutral line, due to the tensile stress mentioned in connection with section AG of Fig. 8 of the paper. The writer has had webs of presses split at S in Figs. 2 and 3 and somewhere along NN in Fig. 1.

3 There are many cross-sections for press frames, but the most usual are shown in Figs. 2 and 3. These are equally good as regard resisting vertical stresses on the line AA (Fig. 1). In regard to torsional and lateral bending stresses, Fig. 3 has much the advantage. Presses are frequently subjected to other than the normal vertical stresses on account of large dies striking the work irregularly, perhaps

on one corner at a time, thus having a tendency to bend and twist the frame of the machine. Obviously, no better shape than Fig. 3 could be contrived for all these stresses and, furthermore, such a



FIGS. 2 AND 3 COMMON FORMS OF PRESS FRAMES

form of machine is much more beautiful, as well as more solid and rugged in appearance. The form shown in Fig. 2, however, is in more general use, doubtless because it is cheaper to make, both as regards pattern-making and molding.

4 In any case, the fillets shown at F (Figs. 2 and 3) should be made very large to avoid cracking in cooling as is very likely to happen on account of the massive tensile member joining the much lighter web.

WILFRED LEWIS. Thirty years ago punch and shear frames were made with a section as shown on the left of Fig. 1 herewith and

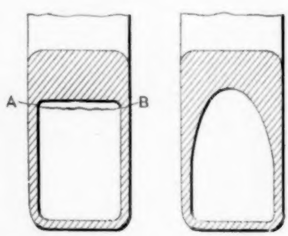


FIG. 1 SECTIONS OF PUNCH AND SHEAR FRAMES

they always split at AB. I came to the conclusion that the weakness in all such frames was in the web and I changed the form to that on the right of Fig. 1. I have never heard of a broken frame of this section.

2 There is no mystery about the breakage at AB, for if tension or compression is running in a given direction it cannot be deflected without putting a strain on the web, which must be strong enough to deflect these forces around the curve. The reason why curved beams do not develop their estimated strength is in my opinion simply due to the fact that no attention is paid to the section of web necessary to deflect the tensile stress in the flange.

John S. Myers.[1] A careful consideration of the paper by Professor Jenkins seems to indicate five things:

a That for solid sections of cast iron, such as specimens Nos. 1, 2 and 3, the common beam formula comes much nearer to an expression of the facts than does either that of Résal or of Pearson and Andrews.

b That such specimens fail at a stress approximately 86 per cent of the ultimate tensile strength of the test specimen when computed by the common beam formula, which may be due to any one of a number of causes, such as un proportionality of stress to strain beyond the elastic limit, shifting of the neutral axis due to inequality of the coefficients of elasticity for compression and tension, the curved form of the specimen, or deformation due to shear parallel to the neutral plane.

c That the limited number of the tests on solid sections and the small size of the specimens used still leaves room for considerable uncertainty as to the behavior of larger castings.

d That the safest course for designers to pursue until more light has been shed upon the subject is to continue as heretofore, that is, to use the common Unwin formula but to keep the working stress between 1500 and 2000 lb. per sq. in., thus insuring rigidity, and pay no attention to the probable ultimate sustaining capacity.

e Finally, that the matter really seems of little practical importance if confined wholly to solid sections of cast iron, as such sections are notoriously uneconomic and hence seldom used.

2 In the matter of the I-sections experimented upon, the peculiar manner in which failure occurred was to be anticipated, for, while the design of the specimen chosen is quite a common type, it is none

[1] 2456 Almond St., Philadelphia, Pa.

the less an improper and entirely illogical construction, as was pointed out by the writer in an article appearing in the June issue of Machinery, from which the following extract is made: "The application of a little common sense should make it apparent that if we have a flange in tension or compression we must not suddenly give it a 90-deg. or 180-deg. bend and expect the stress in that flange to go shooting around the corner like a cable car, but we must *provide means for the*

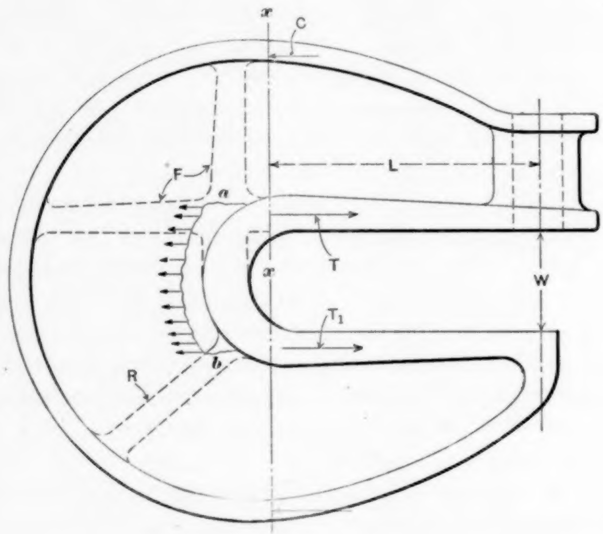


Fig. 1 Bull Riveter Frame of Usual Design

distribution of that stress and carry it where it may meet an equal and opposite load to balance it; for no stress induced by flexure springs suddenly into existence or dies out suddenly; it is gradually built up and gradually dies out again;" so instead of trying to deflect nature from her course we should humor her.

3 "As an example of improper construction, take the bull riveter frame shown in Fig. 1. Here it is quite obvious that if the web were to part along the line *ab* there would be nothing to balance the loads T and T_1 in the tension flanges, and failure to balance these forces would mean failure for the entire frame. The total flange loads are, approximately,

$$T \doteq \frac{WL}{h} \quad \text{and} \quad T_1 \doteq \frac{WL}{h_1},$$

and if w = thickness of web, the average unit tension distributed over the web along line ab

$$t = \frac{2\,WL}{hw\,(ab)} \quad \text{[1]}$$

or, if h_1 does not equal h,

$$t = \frac{T+T_1}{w\,(ab)} = \frac{WL}{w\,(ab)}\left(\frac{1}{h}+\frac{1}{h_1}\right) \quad \text{[2]}$$

4 "From this it would appear that the sectional area of the web along line ab should be approximately equal to the combined area of the *two* tension flanges, and were it not for the fact that it is necessary to thicken up the web at this point in order to avoid shrinkage cracks, there would probably be more frequent failures due to this improper construction."

5 That this point just back of the flange is the weakest place in the frame has been fully demonstrated by the tests conducted by Professor Jenkins and it seems that the obvious thing is to correct the construction by adding a diagonal rib as indicated by the dotted lines at R or else by continuing the flanges as at F (Fig. 1). The latter would permit the stress in the flanges to die out gradually in a natural mannner and from a theoretical viewpoint would be the more logical method. The method of the single diagonal rib is an attempt to deflect the stress generated in the vertical flanges "around the corner" by the application of a resultant force in the rib, which reinforces the web at this critical point. This method is probably more economical of material than the former one. To omit all such ribs and permit the full flange load to concentrate upon the web is clearly an improper distribution of material and the existence of many such designs is no doubt due to a misconception of fundamental principles.

6 It would seem that most students are taught that any stress due to bending is entirely dependent upon the bending moment at the section and that the only necessary requisite is that the internal forces must balance the external ones. Thus we find designers who pay absolutely no attention to the manner in which these internal forces are built up by the transference of the vertical shear from section to section. Now the method I have proposed in connection with equation 2 is open to the objection that it is not very exact,

owing to the somewhat indefinite nature of the distance *ab*, but it at least has the justification of recognizing the real cause of the weakness.

7 The absurd results given by the Pearson-Andrews formula are not surprising because the principal quantity in this analysis is the radius of curvature of the gravity axis P_o of successive sections and this quantity has absolutely no mathematical relation to the flange curvature, as is clearly shown by Fig. 2. Here the rear flange of a C-frame is shown concave and of such a curvature as to make the gravity axis curve *ABCDE* a straight line at point *C*, in consequence of which $P_o = \infty$, while OF = the flange curvature.

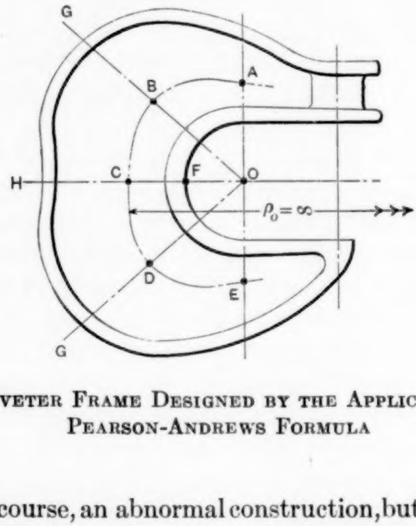


FIG. 2 RIVETER FRAME DESIGNED BY THE APPLICATION OF THE PEARSON-ANDREWS FORMULA

8 This is, of course, an abnormal construction, but while improbable is not at all impossible; in fact the compression flange is often considerably less in area at point *H* than at point *G*, which has an effect upon the curvature of the gravity axis similar to a reverse curve in the rear flange, although not so readily seen. For such a case the Pearson-Andrews formula reduces to the same value as the usually applied Unwin formula, yet it is clear that there is just as rapid transition of stresses around the throat as there would be were the value of P_o equal to *OC*.

9 I would like to present a problem for solution which should have some bearing on the subject under consideration but more strictly a problem relating to flexure in general than to the specific case of curved machine elements. As is well known, the common theory of

flexure assumes that any section being plane before flexure remains so after flexure; hence, stress varying as strain, the stress varies directly as the distance from the neutral plane. Now stresses due to flexure are induced by the transference of vertical shear from some point on the member to some other point and flexural stresses are thus built-up stresses, i.e., they result from a process of growth. So long as the flexural stress is receiving an augment there exists a shear on the neutral plane and all planes parallel to it and since any stress, be it tension, compression or shear, must of necessity produce a corresponding strain, this horizontal shear must be accompanied by a sliding upon each other of the so-called fibres. The common theory of flexure recognizes no such deformation, hence it must assume that the coefficient of elasticity for shear is infinite when compared to the coefficient of elasticity for tension or compression. As this is entirely at variance with fact it should be expected that this horizontal shear would have an important effect upon the distribution of the stresses, especially for sections with heavy flanges and comparatively light webs, subjected to a heavy vertical shear, such as the frames of punching and riveting machinery. Briefly, the problem is this: Deduce an equation which shall express the manner in which the stress varies over the cross-section of box and I-sections when taking into account the deformation due to horizontal shear.

S. A. Moss. It occurs to me that the failure of some of the specimens at the junction of flange and web might be due to insufficient fillet, which nullifies any mathematical analysis.

2 I had always supposed that the three types of formulae mentioned were practically equivalent, and differed only so far as minor corrections were concerned. The results seem to show that there is a fundamental difference, however. What is the mathematical reason for this and what mathematical points are taken account of in one formula and not in the others? As I understand the matter, the best that the designer can do is to use formulae 6 and 8 of the Appendix. What values of the experimental constant K does Professor Jenkins recommend?

3 The paper shows how exceedingly weak our mathematical engineering is. There appear to be three points of uncertainty, the fundamental criterion for a safe stress, the law of distribution of stress in a beam, and the mathematical solution of the bent beam problem. It seems to me that a good fundamental criterion is permanent set, and that a part ceases to be useful when the permanent

set reaches some predetermined appreciable amount. According to this criterion, the stress which gives such appreciable set must be known, and the working stress must be a safe fraction of it. In other words, the stress where appreciable permanent set begins could be substituted for breaking stress. This criterion would require that in tests such as those of the present paper, the permanent set at various loads be found from the autographic record by removing most of the load at frequent intervals. The mathematical formulae may apply up to the limit of appreciable permanent set even though they do not apply up to the breaking load.

4 The elastic limit, yield point, or bend in the stress-strain curve, often used as a criterion for safe stresses, may or may not correspond to stress at which appreciable permanent set begins. It is merely a matter of interest, and not particularly important if there is such coincidence, since we can directly use as our criterion the stress at which appreciable permanent set begins.

5 A complication which would have to be taken account of in using this criterion on some materials, such as brass and bronze, is the fact that the first application of a load causing permanent set changes the material, so that it will better stand succeeding loads. In such a case the criterion might be the stress whose second application gives an appreciable permanent set. In the mathematical analysis of the simple or bent beam, it is probable that the application of the maximum shear theory will be of value. This theory was proposed by Guest and Mohr some years ago and has recently been discussed by other writers. It seems probable that this theory will be the basis of all treatment of stresses other than uniform tension and compression in the future.

6 This theory states that the phenomenon in which an engineer is interested is not tearing apart as in tension but sliding apart as in shear, and that the maximum shearing stress at each point is the matter which must be investigated. In other words, the way in which metals fail is by shear, and not by tension or compression considered strictly as such.

7 It seems to me that the combination of these two points, giving as a criterion the shearing stress at which appreciable permanent set begins, would give a rational solution of the present problem.

George Westinghouse stated that it was his belief that most engineers pay too little attention to the time element in castings. Machine members are tested or put into service without giving the

molecules time to adjust themselves so as to relieve the casting strains. Automobile cylinders which are annealed between the rough and finish turnings are more reliable than untreated castings.

E. J. LORING. The greater ease of calculating sections by the ordinary beam formula would make of considerable value any simple means of correcting its results for curvature of the beam. Professor Jenkins appears to infer that the manner of distribution of stress in cast iron acts to supply such a correction, which would be exceedingly important if true.

2 It would seem extremely improbable that such a result, if true for one set of conditions of curvature, depth of gap, etc., would be true for other proportions.

3 Examining the tests, specimens Nos. 1, 2, 3, 10, 11, 14, 15, 16, 18 unquestionably failed at the section under consideration. Of these we have

		per cent
No. 10, T-section (flange out)	$\dfrac{\text{Unit stress by beam formula}}{\text{Unit stress, tension specimen}}$	= 51
No. 11, I-section (flange out)	"	= 77.9
No. 1, plain section "	"	= 85
No. 2, " "	"	= 86.5
No. 3, " "	"	= 87
No. 16, " "	"	= 76.4
No. 18, " " (necked)	"	= 94
No. 14, T-Section (flanged in)	"	=109.7
No. 15, " "	"	=109.3

so that, according to the shape, the results by the beam formula may be 10 per cent greater or 50 per cent less than the tensile test strength of the material, which can hardly be considered a close agreement.

4 The condition of stress on the section lies between the conditions of tension and transverse tests, and if the results by these two methods of test are averaged we would have a very rough approximation to the unit stress under the actual conditions. Where the values of the unit stress by the Résal and Pearson-Andrews formulae are given for the above mentioned specimens, it will be found that in every case but Nos. 14 and 15, (T-section with flange in), the average thus taken lies between the values given by these formulae, apparently indicating that these give a closer approximation to the

actual stress. In Tests 14 and 15 the average is greater than by either formula.

5 I fully agree with conclusion *e*, particularly as to the chances of error in the use of these formulae, but I distinctly disagree with conclusions *b* and *d*.

The Author. Mr. Christie infers that failure behind the flange of C-shaped castings is due to sudden change in cross section and refers to Professor Marburg's tests on steel I-beams which failed by lateral deflection of top flange and by twist of web, manners of failure not observed in C-shaped specimens of cast iron and not applicable to his statements. The method of analysis suggested by Mr. Christie has hardly enough rational bearing to commend its use, although it seems to fit this particular case very well.

2 There is no reason for believing the internal stresses due to cooling were sufficient to affect the results, for reasons given in Par. 15*a*. The age of the castings varied from two to six weeks.

3 In Professor Rautenstrauch's tests of castings, referred to in his discussion, deflection readings were taken, which, when accurately plotted and a curve drawn through the points, show no sudden change in the proportionality between load and jaw opening; but in order to locate this point for comparison he uses two straight lines instead of a curve, and since it is possible to draw an infinite number of tangents and chords to a curve he is able to get intersections anywhere he desires.

4 The lines he gives are in contradiction of such authorities on the elastic properties of cast iron as Kupffer,[1] Love,[1] Saint Venant,[1] and Professor Pearson,[1] as well as any well known authors on the strength of materials. Professor Pearson, who is responsible for the formula in question and should be satisfactory authority on this subject, states on p. 733 that "Hooke's law does not hold for cast iron even in the case of very small strains." Professor Morley states that the elastic limit of cast iron is at almost zero.

5 The I-beam shown in Fig. 1 was cast from the same heat as the curved specimens and was used in studying the resistance to horizontal shear. This specimen was tested as indicated in Fig. 1 and the autographic record is presented in Fig. 2, which in no way suggests a sudden change in the rate of deflection similiar to that shown in Professor Rautenstrauch's diagrams.

[1] History of Elasticity, by Todhunter and Pearson, Vol. 2, Pt. 1.

6 The elastic laws for cast iron are given in Par. 1 and Par. 2 of the Appendix and when plotted show no point that will permit the use of Professor Rautenstrauch's method of analysis.

7 The sudden change in the rate of stretch of his test bars is easily accounted for by the fact that they were stressed to that point in testing the casting, it being known that an artificial elastic limit can be given cast iron by previous loading.[1]

8 The curves shown in Fig. 3 were drawn by the autographic recorder and are undoubtedly more accurate than those given by Professor Rautenstrauch. They show no elastic limit or yield point, as stated in Par. 29.

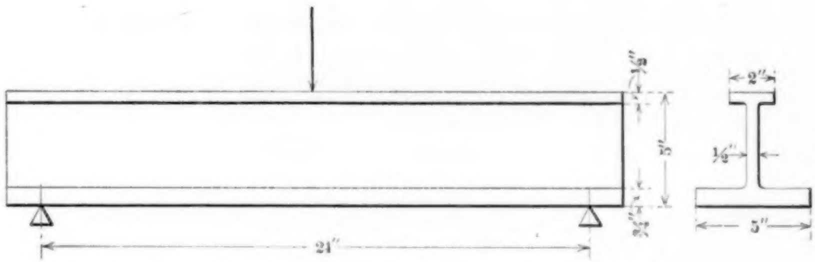


FIG. 1 I-BEAM USED FOR STUDYING RESISTANCE TO HORIZONTAL SHEAR

9 His criticism of Par. 13 is that it is unjust and misleading. It is admitted that the Pearson-Andrews formula is not true for breaking load and as the object of these experiments, as stated in Par. 2, was to determine the strength of the castings, it is not easy to see how the formula can give other than absurd results for this condition. In The Journal for February he stated that "the formula has not as yet been sufficiently well developed to determine its usefulness in establishing proportions for sections other than those at right angles to the load." According to this statement the formula does not apply to his tests on cast-iron specimens because they did not fail at right angles to the load.

10 It occurred to the author to use Professor Rautenstrauch's method of analysis, but investigation showed that it is not applicable to cast iron and has the following objections when used for steel:

[1] Trans. A.S.M.E., Vol. 17, p. 694.

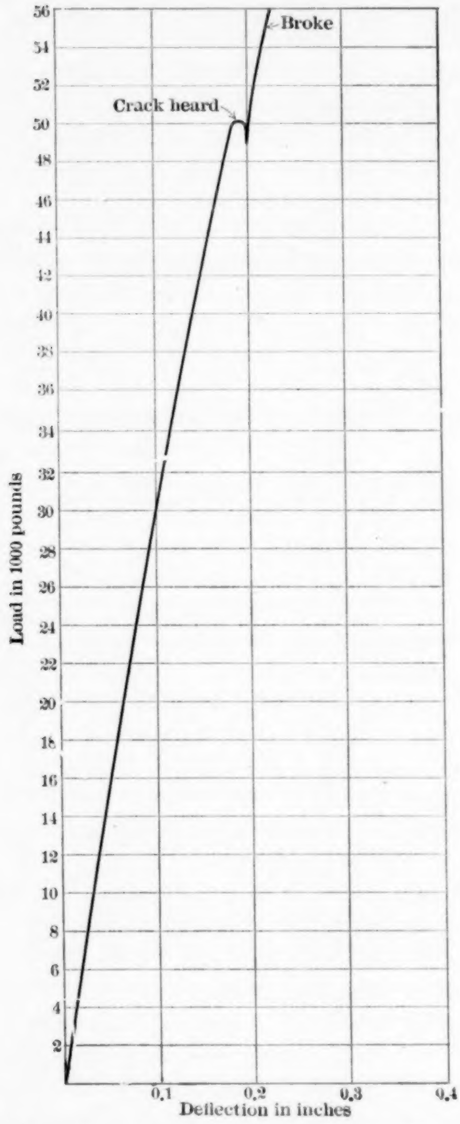


FIG. 2 FULL-SIZE AUTOGRAPHIC RECORD OF BEAM IN FIG. 1

a The formula only applies to specimens with curved spines.
b It is only true for one section of the specimen.
c The load-deflection curve gives the total deflection or the deflections of an infinite number of sections.

d The specimen may yield first at a section some distance from the one assumed by this method without detection.

e It is possible for a casting to yield in the straight portion similar to a straight cantilever beam while the calculation is made for a section in the bent portion, which would be quite erroneous.

11 From a theoretical standpoint there is no doubt about the accuracy of the Pearson-Andrews formula for stresses within the elastic limit of materials that obey Hooke's law; but it is not true for cast iron, even for the smallest loads. If someone should substitute the exponential or parabolic laws for Hooke's law in the formula he would have reasons for his plea of defense when the formula is placed on trial.

12 It appears to the author that Professor Rautenstrauch's calculations based on the sudden change in the rate of stretch for cast iron, the existence of which is denied by the best authorities, and a formula based on an elastic law that is not true for cast iron, cannot be taken seriously. They were, moreover, applied to two test specimens only.

13 The author infers that Mr. Hess, in his discussion, proposes that we should make a critical study of the elastic properties of cast iron and modify our formulae to suit the actual conditions, which is a point well worth considering.

14 The testing apparatus he mentions is probably that described by Mr. E. Rasch in a paper before the Copenhagen meeting of the International Association for Testing Materials. The use of this method involves the coefficients of heat conductivity and radiation.

15 The method of analysis suggested by Mr. Myers is less accurate and has the same objections as the similar method given in Par. 15*b* of the paper. A much more logical method and one that recognizes the real cause of the weakness is given in Par. 15*c*.

16 His method of permitting the stress in the flange to die out gradually and not go shooting around the corner like a cable car by adding a diagonal rib is certainly insufficient because the casting fails along *ab*, which is between the proposed ribs. This may be done by increasing the thickness of the web where the weakness exists.

17 Mr. Myers states that stresses due to flexure are induced by transference of vertical shear from some point in the member to some other point and asks that an equation be deduced to express the manner in which stress varies over the cross section of box and I-sections when taking into account the deformation due to horizontal shear.

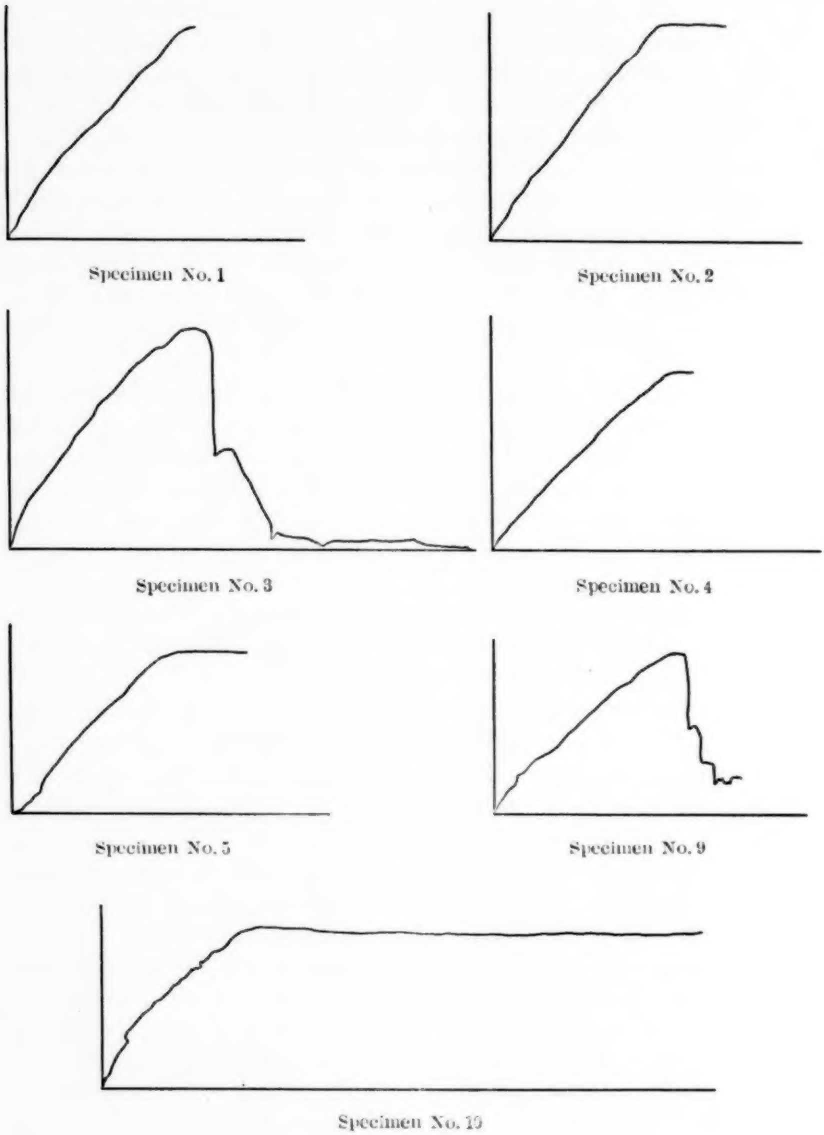


Fig. 3 Autographic Stress-Strain Curves

18 Fig. 4 shows the forces acting on a very small rectangle at the point A in Fig. 5. The normal forces tt are due to bending, whereas the forces s_v s_v are due to vertical shear. Now it is easily seen that these two sets of forces wanted cause the rectangle to rotate and it is necessary to introduce the forces s_h s_h to effect equilibrium. Hence, the horizontal shearing forces s_h s_h must always equal the vertical forces s_v s_v.

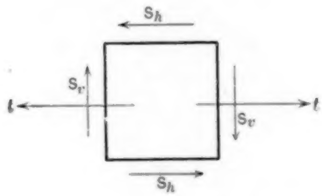


FIG. 4 FORCES ACTING AT A (FIG. 5)

19 The total vertical shear on the section x distance from the support, in Fig. 5, is

$$Q = \frac{d\,M}{d\,x}$$

which is the rate of change of the bending movement and is analogous to acceleration. The intensity of shear at any point in the section may be expressed by the equation

$$q = \frac{Q}{I\,z} \int_{y}^{y'} z\,y\,dy$$

where

q = unit shearing stress at y distance from the neutral axis
Q = total shear on section
z = breadth of section at y distance from neutral axis
I = moment of inertia

The normal stress at any point in the section is determined by the formula

$$S = \frac{My}{I}$$

20 An idea of how the apparent stresses S and q, are distributed over various sections of a rectangular beam may be gained from the diagrams given in Fig. 6.

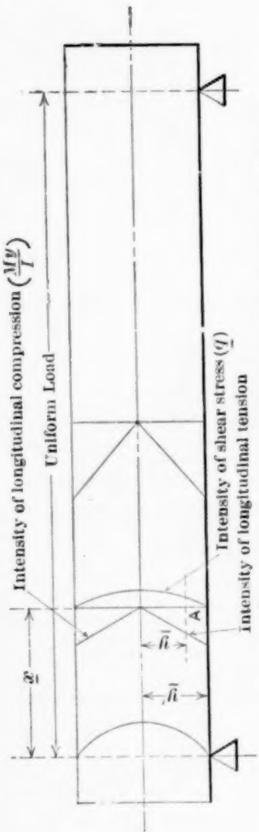


Fig. 5 Distribution of Stresses in Rectangular Beams

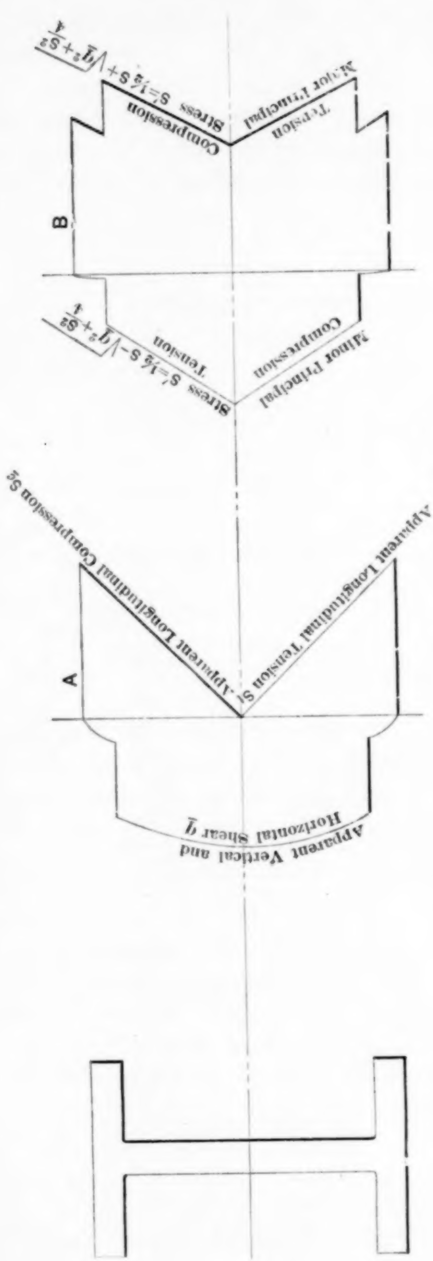


Fig. 6 Distribution of Stresses in I-Beams

21 The maximum resulting shear at any point due to the stresses S and q is

$$q' = \sqrt{q^2 + \frac{S^2}{4}}$$

and makes an angle Θ with the neutral surface such that

$$\tan 2\,\Theta = \frac{S}{2\,q}$$

22 The principal unit stress at any point is

$$S' = \tfrac{1}{2}\,S \pm \sqrt{q^2 + \frac{S^2}{4}}$$

and makes an angle ϕ with the neutral surface such that

$$\tan 2\,\phi = -\frac{S}{2\,q}$$

23 The equivalent normal stress, namely, a linear stress that would produce a deformation equal to that actually produced by S and q is

$$S = \frac{(1 - \lambda)}{2} + \frac{(1 + \lambda)}{2}\sqrt{4\,q^2 + S^2}$$

where λ is Poisson's ratio.

24 Fig. 6 shows how the apparent and principal stresses are distributed over a section of an I-beam, diagram A showing the variation of the apparent stresses S and q and diagram B the variation of the principal stresses S', the direction of which may be found at any point by determining the value of ϕ. Diagram B shows how the stress at the juncture of the flange may be greater than the stress at the outer fibre. The value of q' may also be sufficient to produce failure.

25 The step in the curve shown in Fig. 2 is due to internal failure caused by the principal stress.

26 The above discussion is only applicable to straight beams and does not pertain to the spine of a curved beam because of the absence of shear in that portion. This fact may be seen from the inspection of Fig. 7, which represents a C-frame consisting of a solid block C connecting the two straight beams A and B, which consist of two pieces riveted together. The beams are subjected to vertical and horizontal shear, and there exists a tendency to shear the rivets in them, but the piece C, although it may bend, is free from shear.

27 Dr. Moss wishes to know what mathematical points are taken into account in one formula and not in the other. They differ essentially as follows:

a The beam or Unwin formula merely considers the stress due to bending and the direct pull of the load and is based on the same assumptions as the fundamental formula for straight beams.

b The Résal formula takes into consideration the stress due to bending and the effect of curvature.

c The Pearson-Andrews formula considers the stresses due to bending and direct tension, the curvature and lateral contraction.

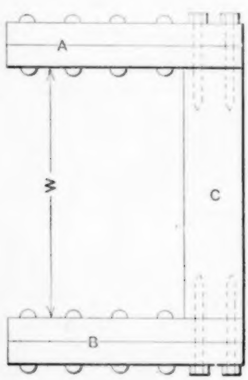


Fig. 7 C-Frame Showing Absence of Shear in C

28 They are all based on Hooke's law and Bernoulli's assumption, neither of which are true for cast iron. The assumption that these are true has been the source of weakness in all rational formulae for cast-iron beams, and all attempts to improve the formulae by basing them on the actual laws governing the properties have been futile owing to the mathematical complications involved.

29 Formulae 6 and 7 of the appendix are for castings having straight spines of rectangular cross-section. The value of K depends on the size of the casting, temperature of power, rate of cooling, and percentages of silicon and carbon. For the specimens tested it has a value of about 7.3.

30 Dr. Moss states that the stress where appreciable permanent set begins could be substituted for breaking stress. Professor Morely

states in his Strength of Materials that slight permanent sets may be detected under very low stresses. As evidence that the permanent set at the breaking point is not very pronounced, Lynde[1] made experiments on 89 girders of 30 ft. 9 in. span, one of which he tested to rupture, and remarked that no permanent set was visible. In view of these statements such procedure would not be practical.

31 Guests' maximum shear theory is only applicable to ductile materials and does not apply to cast iron. The proof of this fact is brought out in an article by the author in Engineering (London), November 12, 1909.

32 The point raised by Mr. Loring in regard to the distribution of stress making corrections for curvature when the beam formula is used, is explained in Pars. 29 and 30 of the Appendix. The distribution of stress tends to make such a correction, but the amount depends upon the proportions of the section and the elastic properties of the material and may be determined by formula 2 and the results obtained by the method described in Par. 6 of the Appendix.

33 In tabulating the percentages of disagreement between the strength of the test bar and the results given by the bean formula, he omitted No. 17 and introduced No. 10, which, as stated in Par. 19, had a flaw in the section that failed. Omitting No. 10, the values vary from 10 per cent greater to 23 per cent less, which is closer agreement than the 44 per cent given by the Résal and 73 per cent by the Pearson-Andrews formula.

34 He also suggests averaging the tensile and transverse strengths of the specimens and comparing the results with averages made between the values given by the Résal and Pearson -Andrews formulae. Because such a comparison gives closer agreement than the above, he concludes that conclusion *b* is not justifiable. This unique method of comparing results has no rational significance and is not sufficiently well grounded to disprove conclusions *b* and *d*.

[1]History of Elasticity, Vol. 2, Pt. 1, p. 866.

GAS ENGINES FOR DRIVING ALTERNATING-CURRENT GENERATORS

By H. G. Reist, Published in The Journal for June 1910

ABSTRACT OF PAPER

This paper points out briefly the problems that must be solved to obtain the best parallel operation of alternating-current generators when driven by means of gas engines. While some assistance can be given when designing the generator, the most satisfactory solution of the problem is so to design the gas engine that even rotation is obtained as nearly as possible. This should be done without the use of a very heavy flywheel.

DISCUSSION

P. M. Lincoln. I am obliged to take issue with Mr. Reist on one of the most important conclusions in his paper, that contained in Par. 6, in which he states that "if there were no inertia, the rotating parts of generator and flywheel would quickly get into synchronism, reducing and almost eliminating the cross-currents." The truth of this statement depends entirely upon the definition of cross-currents. It is usually understood that if the flow of energy from all of the alternating-current units in parallel is not essentially the same at all times there are said to be cross-currents. If this definition is accepted, Mr. Reist's statement is entirely unfounded. It is obvious that the flow of energy from a gas engine or any reciprocating engine is not uniform. There are some instances when it is a maximum, others when it is a minimum and in some cases it is even a minus quantity, as for instance when compression is taking place. If there were no inertia in the gas engine the flow of energy from the alternator into the circuit would be just as uneven and differ just as much from the uniform flow as the generation of this power within the cylinders. The fact that a gas-engine-alternator combination possesses inertia introduces another element into the energy flow equation. With inertia the rate that energy flows into the circuit is equal to its rate

of generation minus its rate of storage in the reciprocating and rotating parts. By designing these parts properly the flow of energy into the circuit can be made much more uniform than its rate of generation. If gas engines and their generators could be built without inertia the condition that would then obtain would be far from ideal, as Mr. Reist states. In fact, the phenomenon which we know as cross-currents would be much larger if inertia were entirely absent than in the ordinary cases with which we have to deal.

2 Mr. Reist also makes the following statement with which I cannot agree: "If the flywheel is very large the currents which it may be practical to allow to flow between the machines may not be able to draw them together at all." While this may be true as an isolated statement, it has no bearing upon the problem in hand. With very large flywheels there would be no occasion for large currents to flow between the various units in parallel. In general, the larger the flywheel the more uniform will be the rotation and therefore the more uniform the flow of energy from that combination as compared with its rate of generation. Hence what we know as cross-currents will be reduced to a minimum.

3 There is one very important element in parallel operation of alternators which Mr. Reist neglected to mention. If any generator is displaced from its normal position in its magnetic field, a force equivalent to a spring at once acts to return it to the normal position. The greater the departure from normal position the greater will be the force acting to return it. Any mass which contains such an element has a natural period of vibration. In the combination of alternator and engine the natural period of vibration will depend upon the inertia of the moving parts and the electrical and magnetic characteristics of the generator. If the impulses imparted to this mass by the engine are in resonance with the natural period of vibration, a state of affairs will exist which makes it very difficult and sometimes impossible to operate alternators in parallel. It is exceedingly important, therefore, in designing gas engines and the connected alternators to make sure that the natural period of vibration of the rotating parts of the combination is not in resonance with the impulses which may be imparted by the gas engine.

4 Another thing which Mr. Reist neglects to mention is the possibility of missing engine power strokes. It is usual to design flywheels on gas engines so that the departure from uniform rotation will not be excessive even when a power stroke of the gas engine is missed. It is evident that if the flywheels are made large enough to take care of

this contingency there will be more than ample capacity when the explosions are taking place uniformly. So long as normal conditions obtain, that is uniform explosion, the normal operation of gas engines in parallel is usually better than that of steam engines in parallel.

The Author. Mr. Lincoln's criticism regarding cross-currents on generators is apparently a matter of definition. Cross-currents flow between generators from a number of causes, such, for instance, as the difference in wave shape of the several machines, or differences in excitation and currents flowing between the generators due to the generators being out of phase. The first two are so-called wattless currents and the last is energy current. This is the class of cross-currents to which I had reference in my paper. It does not seem to me that the fact that the flow of energy from the engines is not uniform would necessarily establish cross-currents between the machines. It would simply mean that as a generator runs more slowly it gives up less power to the system than when running faster.

2 I agree with Mr. Lincoln that in general the larger the flywheel with any given engine the more uniform will be the rotation, yet I believe it is also true that if there is any tendency for the sets to hunt, the larger the flywheel the greater will be the cross-current that will flow between the machines and the greater will be the electrical disturbances. The natural period of vibration must be avoided in the design of the flywheel and it must be large enough so that the missing of a power stroke is not serious. These difficulties may, however, be corrected by having many cylinders and thus more impulses per revolution, as well as by having a heavy flywheel. In respect to the point under discussion, I would consider that engine the best which, with a given degree of variation from uniform velocity during any given revolution, uses the lightest flywheel.

FREIGHT TRAIN RESISTANCE

By Prof. Edward C. Schmidt, Published in The Journal for May 1910

ABSTRACT OF PAPER

The paper deals with the results of tests made upon the Illinois Central Railroad by the Railway Engineering Department of the University of Illinois to determine the resistance of freight trains.

Train resistance is defined in pounds per ton and speed in miles per hour, and expressed for trains of various average weights per car, the marked influence of car weight being indicated by the following facts:

At a speed of 5 miles per hour the resistance of a train in which the cars average 75 tons in gross weight is 3 lb. per ton, whereas for a train whose average car weight is 15 tons the resistance is 7½ lb. per ton, a difference of 150 per cent. At higher speeds the relation between resistance values is about the same as at low speeds. At 40 miles per hour, for example, the resistance of a train of 75-tons average weight per car is 5½ lb. per ton, while for a train of 15-tons average weight per car it is 13½ lb. per ton.

The trains tested varied in weight up to 3000 tons. The tests were made over main-line track of good construction, laid with 85-lb. rail, during weather when the temperature was above 30 deg. and when the wind velocity did not exceed 20 miles per hour. The test data are displayed in the paper and the results fully discussed.

DISCUSSION[1]

T. S. Bailey. In Par. 36 it is stated that the lowest temperature recorded at any time during any test was 34 deg. fahr. and the highest 82 deg. fahr. It is further noted that the temperatures at the beginning and end of tests are recorded and that no mean temperature for the whole run is given. It would appear that a correction for temperature is essential, as the variation in density of air between 34 and 82 deg. fahr. is about 10 per cent, which of course affects the resistance by an equivalent amount. While the author has given but meager details of his calculations, there is nothing to indicate that such correction has been made. It would appear reasonable, considering the

[1]This paper was presented in St. Louis on May 28 at a joint meeting of the Society with the Engineers Club of St. Louis and at the Spring Meeting at Atlantic City on June 2. The discussion at both meetings has been combined.

amount of work and care that has been expended in obtaining these data, that all possible refinements should be applied and that all resistance curves be confined to certain temperature limits. It is believed that, where the temperature difference between the start and finish of any test is great, correction should have been made and an average temperature for the run obtained.

2 The writer believes also that the greater resistance in winter is to some extent explained by the greater density of the air.

PROF. WM. G. RAYMOND. Professor Schmidt has accomplished at least one good thing by his experiments on freight train resistance in that seemingly he has conclusively settled the disputed point of the increase of resistance with speed. The writer has never been able to accept the statements recently made that freight train resistance is essentially a constant between speeds of 10 and 35 miles per hour, and this set of experiments seem conclusively to disprove such statements.

2 It seems desirable to discuss these tests with reference to the makeup of the trains as well as with reference to the weights. Professor Schmidt mentions the possibility of expressing the facts presented in Fig. 11 by a single equation involving only the first power of the three variables, R, S, and W, and it is desirable that a single expression be found if possible.

3 In attempting to find such an expression, the writer discovered that one law apparently fits the observations for trains with an average car weight of 45 tons and upwards; another law fits those between 25 and 40 tons; but it was impossible to determine whether the curve for the light 15-ton car belongs within the heavier or the medium weight group.

4 In looking for a reason for this it seems that all of the very heavy trains are made up largely of loaded gondola cars, and the lightest trains are likewise largely made up of empty gondola cars, whereas almost all of those trains having an average car weight between 25 and 40 tons are wholly or largely made up of box cars. It is entirely conceivable that these cars, with their greater surfaces, may give resistance following a different law from that applying to the resistance of trains of gondola cars. It would seem that there might very well be two or even three general expressions: one for box cars, one for gondola cars, and possibly one for a combination of the two, although this is perhaps a needless refinement. The values obtained for a train with an average car weight of fifteen tons are perhaps too

small for anything but empty gondola cars, and an equation which is supposed to represent the resistances of average trains (if trains of average makeup can properly be spoken of) should give resistances somewhat higher than those of Professor Schmidt's table for the light-weight trains.

5 The writer has attempted to devise a single equation that will express what the curves of Fig. 11 and the figures in Table 3 show, and has succeeded in finding a comparatively simple one which he has tested for each of the car weights given in Table 3 for speeds at intervals of five miles from 5 to 40 miles per hour. Except for the 15-ton

TABLE 1 COMPARISON OF RESULTS BY DIFFERENT FORMULAE

Speed m.p.h.	Car Weights—Tons												
	15	20	25	30	35	40	45	50	55	60	65	70	75
5	7.6	6.8	6.0	5.4	4.8	4.4	4.0	3.7	3.5	3.3	3.2	3.1	3.0
	8.6	6.9	5.8	5.1	4.6	4.2	3.9	3.7	3.5	3.4	3.2	3.1	3.0
10	8.2	7.3	6.5	5.8	5.2	4.7	4.3	4.0	3.7	3.5	3.3	3.2	3.2
	9.2	7.3	6.2	5.5	4.9	4.5	4.2	4.0	3.8	3.6	3.4	3.3	3.2
	8.8	7.9	7.0	6.3	5.6	5.1	4.6	4.2	3.9	3.7	3.6	3.5	3.4
15	9.9	7.9	6.7	5.9	5.3	4.9	4.6	4.3	4.1	3.9	3.7	3.6	3.5
	9.6	8.5	7.6	6.8	6.1	5.5	5.0	4.6	4.3	4.0	3.9	3.8	3.7
20	10.6	8.5	7.2	6.4	5.8	5.3	5.0	4.7	4.4	4.2	4.1	3.9	3.8
	10.4	9.3	8.3	7.4	6.7	6.0	5.5	5.0	4.7	4.4	4.2	4.1	4.0
25	11.5	9.3	7.9	7.0	6.3	5.8	5.4	5.1	4.8	4.6	4.4	4.3	4.1
	11.3	10.0	9.0	8.0	7.3	6.6	6.0	5.5	5.1	4.9	4.7	4.5	4.5
30	12.5	10.1	8.6	7.6	6.9	6.3	5.9	5.6	5.3	5.0	4.9	4.7	4.5
	12.3	10.9	9.7	8.8	7.9	7.2	6.6	6.1	5.7	5.4	5.2	5.0	4.0
35	13.5	11.0	9.4	8.3	7.5	7.0	6.5	6.1	5.8	5.6	5.3	5.1	5.9
	13.4	11.8	10.6	9.5	8.6	7.9	7.3	6.8	6.3	6.0	5.7	5.6	5.5
40	14.7	12.0	10.3	9.1	8.3	7.6	7.1	6.7	6.4	6.1	5.9	5.7	5.4

car the discrepancy between the results of the single expression and the results of Table 3 is not more than 6.4 per cent. In no single column is there an average discrepancy of more than 5.3 per cent, and in the table as a whole the average discrepancy is not more than 2.9 per cent. Where quantities are as small as those shown in Table 3 of the paper so that an error of one unit in the last place may mean as much as 3 per cent, and where the inaccuracies of observation are as great as they are in the case of train resistance, this close agreement of a single equation with so many observations would seem to be somewhat remarkable and to warrant its use, since it does express a single general law as against thirteen general laws. The single equation is as follows:

$$R = \left(1.5 + \frac{100}{W}\right)\left(1 + \frac{S}{100}\right) + \frac{S^2}{125\sqrt{W}}$$

6 The resistances computed by this formula are compared with those in Table 3 of the paper in Table 1 herewith, the upper figures being those in Table 3, and the lower figures being those found by the formula. The last term may be simplified without seriously affecting the formula. If it be made $\frac{S^2}{800}$, there will be no discrepancy greater than ten per cent outside of the first column, and the discrepancies in the first column will be very much less except for low speeds.

7 This paper of Professor Schmidt's is the most comprehensive and authoritative discussion of freight train resistance as a whole that has as yet appeared, and the writer has been interested to compare the results of his investigation with the equation devised by Sanford L. Cluett to fit the curve for fully loaded trains published by the late A. M. Wellington, filling in the particular coefficients and numerical quantities to make it conform as nearly as possible to the most recently published values of some three years ago. This equation is

$$R = 3.5 + 0.0055\ S^2 + \frac{16}{(S+1)^2}$$

The last term should not be considered in comparing values from this equation with Professor Schmidt's values because it does not effect resistances at the higher speeds and is introduced simply to give the high resistances at starting, which Professor Schmidt has eliminated. Considering Professor Schmidt's experiments with trains having an average car weight of 45 tons, consisting of box cars and gondola cars almost fully loaded, which could perhaps be called average trains, it is found that this previously published equation agrees almost exactly up to a speed of 20 miles per hour, beyond which the formula gives results too great. This fact suggested modifications of the coefficients of the formula, and it was found that by writing the equation

$$R = 4.1 + 0.002\ S^2$$

an almost exact coincidence would be obtained throughout the entire list of speeds from 5 to 40 miles per hour.

8 If this expression can be multiplied by some coefficient involving W, it may be possible to drive an equation to fit variations in both average car weight and speed. After trying several such coefficients, one was found which, while it produced greater discrepancies in some

parts of Table 3 than does the independent equation above derived, yet in other parts of the table it gives results agreeing more closely than those of the independent equation. On the whole, it is a simpler equation than the latter and gives results averaging as well. The resulting equation is

$$R = (4.1 + 0.002\,S^2)\left[1 + \frac{5}{9}\left(\frac{45 - W}{W}\right)\right] + \frac{16}{(S+1)^2}$$

which may be simplified to

$$(1.8 + 0.0009\,S^2)\left(1 + \frac{56}{W}\right) + \frac{16}{(S+1)^2}$$

and a slight modification of constants may improve the result. The last term will be used only when considering slow speeds at starting and not when considering slow speeds after the train is well in motion. It is considered worthy of note that Professor Schmidt's results for what may be called his average train agree so closely with the modified Wellington curve.

S. A. Moss. We are accustomed to think of the coefficient of friction as a constant, but as a matter of fact, in most cases of film lubrication the coefficient of friction is not a constant quantity, but changes with the load. That is, when there is a complete oil film between the journal and the lining, the actual friction force is not increased by additional bearing pressure. This fact is well known for high-speed journals with a well-maintained oil film, and properly applies to car journals, where there is usually very good lubrication. Hence it is quite natural that the friction per ton should decrease with the load.

F. W. Dean. Attempts have been made for many years to determine train resistance, but each new experiemnt is inconsistent with those which have preceded it and we are still far from the real solution of the matter. This is probably due to the inefficient lubricating system used in car journals. The boxes are filled with wool waste, which is supposed to have elasticity enough to keep it up against the bearing, requiring the lubricant to reach the journal by capillary attraction and by jarring, but it is doubtful whether this method is very efficient. Again, as the journey goes on the oil may gradually leak out and the lubrication become even less effective. This simple

method of lubricating car journals will probably continue, although in Europe they take more pains in this direction than we do in this country.

H. G. Stott. Great caution should be exercised in drawing general conclusions from the data presented by these tests. Comparative tests from which general laws can be deduced should be carried out under identically similar circumstances. If the same test train had been used at the various speeds the condition would have been constant and positive conclusions could have been adopted. It appears, however, that each train was made up of cars differing in kind and number. If a train be composed of empty cars with a loaded car at each end, there will be a vertical component of the draw-bar pull acting downward to increase the weight on the empty cars. The air resistance is also quite considerable and is greater per ton for empty cars than for loaded ones. We have found in operating cars on the Interborough system that on cold mornings the load increases greatly on account of the rigidity of track and cars and the increased journal friction due to the condition of the lubricant. We cannot expect to base any general deductions on these tests because they were not made under precisely similar conditions.

G. N. Van Derhoef. A variation of journal friction with change of load may possibly be due to vibration. Any train running on a railroad has a certain amount of vertical vibration and if the energy required to lift the car is given out on the downward movement, thus forming a closed cycle, no energy is consumed. If, however, this cycle is not a closed one, energy is lost through the track to the earth and must be made up by increased draw-bar pull of the locomotive.

2 The number of wheels is usually identical for both heavy and light cars, making the number of points through which these forces are carried to the rail the same in number, but the heavy car will move through an entirely different wave period from that of the light car. The amplitude of vibration will be less for the heavier car, making it ride more steadily and permitting it to travel more nearly in a straight line through space. How much of the total energy required to pull the train is used up in vibration it would probably be hard to demonstrate, but it must be considerable. On an entirely different class of machinery which has quite a vibratory factor, I found a considerable amount of energy being dissipated,

appreciably affecting the amount of power required to run the machinery.

3 I believe that the loss of energy due to vibration affects the resistance relatively more than the variation in the pressure per square inch on the journals. If the oil film is intact, as it must be if the journal runs cool, the difference in friction percentage is slight. The greater steadiness of the heavy car may largely explain the difference in resistance shown by these tests.

F. J. Cole. The record of actual tests given in Professor Schmidt's paper is a valuable addition to the literature on train resistance. The fact that tests were made on 91 miles of track specially surveyed immediately preceding the tests by the engineering department of the University adds to the accuracy and thoroughness of this report.

2 The conclusions which merit the most consideration are those relating to the difference in resistance per ton obtained with cars of various weights and capacities. This fact the author comments upon in Par. 2, stating that while it has been known for some years it has found inadequate expression and but little application. This statement agrees to some extent with my own investigations of the subject, although I am under the impression that the fact is more generally known among railroad men and used in their tonnage ratings than the exact wording of the paper would imply. It may be true that the engineering profession and the readers of technical papers have often failed to grasp the full significance of the fact that train resistance does vary to a great extent in relation to the weight and capacity of cars.

3 In a paper for the Railway Age Gazette [1] I reviewed and summarized the available tests and literature on the general subject of train resistance. Some of the conclusions reached therein are as follows:

a The resistance of freight cars varies greatly with their capacity and weight, and whether empty or loaded.

b The decrease in resistance on level, straight track of 50-ton capacity cars (total weight about 72 tons) is of great significance in estimating tonnage ratings on low-grade roads. This decrease in resistance becomes of gradually less importance with increase of grade.

c The resistance of American freight cars is practically the same between the limits of 5 to 10 and 30 to 35 m.p.h.

[1] Railway Age Gazette, Aug. 27 to Oct. 8, 1909.

d The journal friction is greatest at starting, rapidly decreasing and gradually reaching its minimum somewhere around 20 to 30 m.p.h., aftewards slightly increasing or remaining constant.

e The journal friction with good lubrication, within the limits of railroad pressures, probably varies inversely as the square root of the pressure.

f With large-capacity loaded cars at freight car speeds on good track, journal friction forms a large percentage of the total resistance.

g The condition of the track, stiffness of rails, etc., are important factors in train resistance, because much energy is expended on poor track in dampened oscillations which cause an absorption of energy, and concussions which cause principally an increase in flange friction.

4 The tonnage ratings of a number of important railroads, such as the Pennsylvania, and the Chicago, Burlington and Quincy, are based on the fact that the resistance of freight cars varies with the weight.

5 The greater resistance per ton of empty cars than of loaded cars has been recognized in all American tonnage ratings, and different forms of correction introduced having for their object the decrease of tonnage for trains composed either wholly or in part of empty cars. Therefore the fact is recognized that the resistance per ton of the empty or partly loaded cars is greater per ton than for cars fully loaded.

6 The average car weights of 15 to 30 tons in the paper evidently refer to empty or partly loaded cars, the resistance of which must be clearly kept in mind as compared with fully loaded cars of different capacities, as for example, cars of 40,000 to 100,000 lb. capacity.

7 In order to obtain the exact resistance of freight cars between speeds of 5 and 30 m.p.h. it would be well to reduce as far as possible the number of variables so as to simplify the problem. For this reason it would appear desirable, if the conditions of traffic permit, to run the same train repeatedly over the same length of measured track at varying speeds. If a piece of straight level track of only a few miles in length could be selected and be approached on either side at sufficient distance to get up the required speed, the question of resistance at the speeds named could probably be more accurately determined.

8 The Pennsylvania Railroad, in the numerous careful and

thorough investigations made by their test department for a number of years, and Mr. A. C. Dennis' paper entitled "Virtual Grades for Freight Trains," read before the American Society of Civil Engineers December 3, 1903, which gives the results of actual dynamometer tests of over 3000 miles, both agree as to the constancy of freight train resistance between 5 and 30 m.p.h. or at least that the resistance at 30 m.p.h. is not greater than that at 5 or 10 m.p.h. These conclusions, because of the careful and numerous tests involved, demand more than ordinary consideration and constitute one of the chief points of difference from Par. 90 of Professor Schmidt's paper, in which it is stated that there is nothing in the data to support such a conclusion.

9 The condition of the track regarding stiffness, alignment, etc., doubtless has much influence on train resistance. Quoting from Dr. Dudley in his pamphlet Condensed Diagrams of the Inspection of the New York Central and Hudson River Railroad, 1899:

> The ability of one locomotive to draw eighty loaded 60,000-lb. capacity cars in a single train shows what has been accomplished in the way of reducing train resistance by improving the track, motive power and rolling stock. On the light 4½-in., 65-lb. rails the freight train resistance was 7 to 8 lb. per ton, and is now reduced to 3½ lb. on the 5¼-in., 80-lb. rails for the 60,000-lb. capacity cars and long trains. For 80,000 to 100,000-lb. capacity cars loaded it would be still less.

10 If journal friction within the limits of speeds used on railroads remains constant or very slightly increases for 20 or 30 m.p.h., then it is conceivable, with track conditions so perfect that the oscillations, nosing and slewing are reduced to a minimum, that apart from the greater air resistance there would be little or no increased resistance within the limits of ordinary freight car speeds. On the other hand, gaging, alignment and joints may be in such poor condition that a great deal of energy is absorbed in shocks and dampened oscillations, which may account to a considerable extent for the somewhat conflicting results obtained from dynamometer tests. For a given stiffness of rail and at slow speeds, the effect of the shocks and oscillations would not be so marked, but as the speed increased their effect to absorb energy would be very noticeable.

Prof. W. F. M. Goss. In commending Professor Schmidt's paper, I want first to call attention to the fact that it has resulted from the work of one of unusual experience in the field with which it

deals. Professor Schmidt became responsible for the first dynamometer car of the University of Illinois in 1894, and he has since had charge of all work in train resistance which has engaged the joint attention of the University of Illinois and the Illinois Central Railroad. The present dynamometer car, a device of superior merit, is of his design. When B. J. Arnold was securing data which he could use as a basis for the first great work of steam railway electrification in New York City, Professor Schmidt and the Illinois dynamometer car were for a considerable period in his service on the New York Central Railroad and other eastern roads. Each year's work has brought some distinct improvement in methods and in the accuracy and significance of the results obtained. The present paper, therefore, which represents work of the last two years, is to be accepted as the culmination of an investigation which has extended over a period of six or eight years in its entirety.

2 The general subject of train resistance has received generous attention during the past year from F. J. Cole, who has published an excellent review of existing literature. Mr. Cole has given a survey of the whole field of experimentation from which the reader may draw his own conclusions as to the value of any given set of results. Professor Schmidt's paper now comes as a distinct addition to this excellent summary of previously existing data, complete and comprehensive and of undoubted reliability. It shows with exceptional fidelity the remarkable efficiency of the heavy-capacity car. Judged by the results here presented, the saving in power brought about by the introduction of the high-capacity freight car constitutes one of the important achievements in the development of modern railroading. The paper is important also because of the accuracy with which it defines the increase in train resistance with increased rates of speed. It is a significant fact, well set forth by Professor Schmidt's results, that among the factors limiting the speed of freight trains the increased resistance of the train itself with increase of speed is of far less importance than the diminishing tractive power of the locomotive which pulls it.

John Balch Blood. In Par. 2 Professor Schmidt mentions that the variation of resistance with train weight has not found adequate expression, but I think it has been thoroughly appreciated and universally acknowledged that varying car weight affects the independent term of train resistance formulae. In 1903 I pointed out the values

of this coefficient in my paper on A Rational Train Resistance Formulae,[1] as follows:

$A = 3$ for heavy freight trains
$A = 4$ for average passenger trains
$A = 5$ for heavy large electric cars
$A = 6$ for medium electric cars
$A = 7$ for light electric cars

TABLE 1 RESULTS GIVEN BY FORMULA.

Weight Car Tons	Miles Per Hour			
	5	10	20	30
15	8.48 7.62 *+0.86*	9.04 8.20 *+0.84*	10.73 9.56 *+1.17*	12.85 11.24 *+1.61*
20	6.76 6.77 *−0.01*	7.22 7.30 *−0.08*	8.55 8.53 *+0.02*	10.20 10.00 *+0.20*
30	5.05 5.38 *−0.32*	5.39 5.80 *−0.41*	6.36 6.80 *−0.44*	7.54 8.05 *−0.51*
40	4.19 4.38 *−0.19*	4.48 4.70 *−0.22*	5.27 5.50 *−0.23*	6.22 6.57 *−0.35*
50	3.68 3.72 *−0.04*	3.94 3.96 *−0.02*	4.62 4.56 *+0.04*	5.43 5.52 *−0.09*
60	3.33 3.30 *+0.03*	3.57 3.50 *+0.07*	4.18 4.02 *+0.16*	4.89 4.83 *+0.06*
75	2.99 3.00 *−0.01*	3.20 3.18 *+0.02*	3.74 3.74 *+0.04*	4.37 4.37 *−0.10*

Formula figures on first line. Prof. Schmidt's figures on second line. Differences in italics.

2 These tests by their nature have eliminated the head wind resistance which is the main part of the second power term of resistance formulae. Yet when results are put into formulae the form

$$R = a + bM + cM^2$$

is used.

[1] Trans. A.S.M.E., Vol. 24, p. 950.

Why not instead take the functional variation as shown by the results themselves?

3 I have taken the results at given speeds and plotted the total resistance per car for the different weights. From observation I

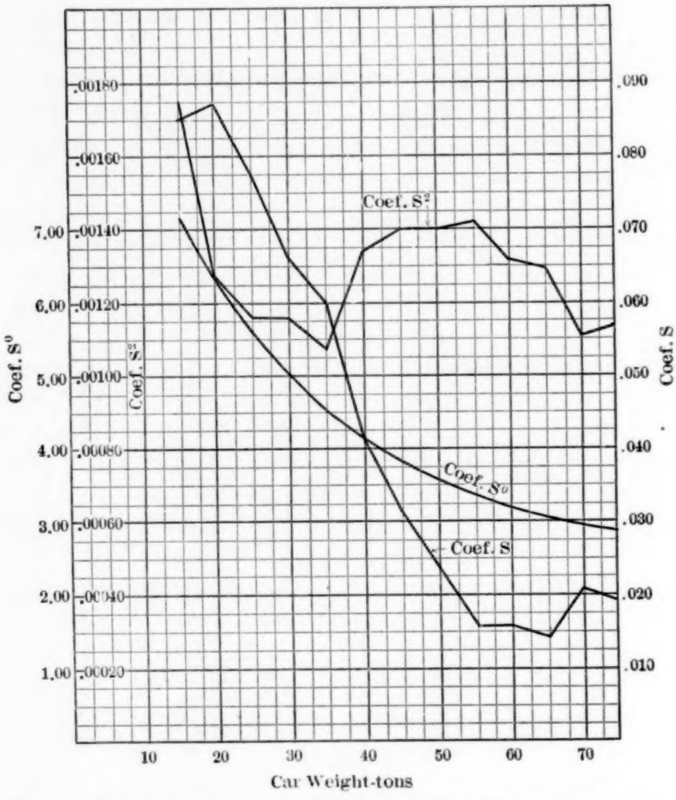


Fig. 1 Coefficients of Formulae in Par. 75 of the Paper

find the resistance common to all to be the side-air resistance, and the function has a value of 1.7. The coefficients of the formulae in Par. 75 were plotted on the smooth curve of rectangular hyperbolic form. This term in reciprocal form would be a linear function, which I found to be

$$\left(1.5 + \frac{100}{T}\right)$$

Taking the exponent 1.7 found above and determining the coefficients

for the track and side resistance terms gives a complete formula for Professor Schmidt's resistance without head-air resistance as follows:

$$R = \left(1.5 + \frac{100}{T}\right) + 0.025M + 0.00466\,\frac{L}{T}\,M^{1.7}$$

where R = resistance, T = weight of one car, M = miles per hour, L = length of one car. Results obtained by the use of this formula at various car weights and speeds are compared with those of Professor Schmidt in Table 1. The differences are less than the variations between observations and it will therefore be seen that with proper functions the multiplicity of formulae is unnecessary and misleading.

Lawford H. Fry. I am disposed to agree with Professor Schmidt that the results he gives may be used with reasonable accuracy for

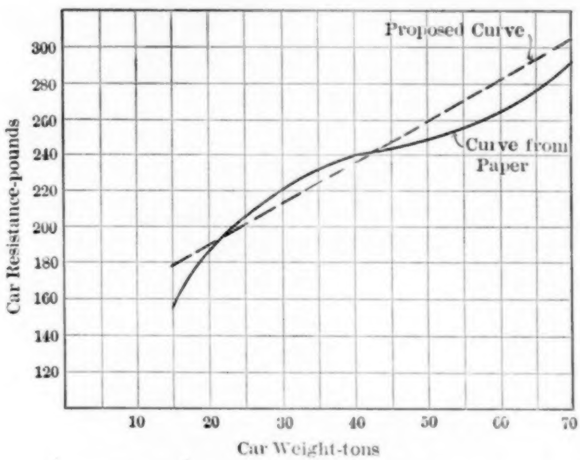


Fig. 1 Comparison of Results by Proposed Formula and by Formulae of Par. 75 of the Paper

calculating the resistance of a freight train, but I should like to suggest a slight change in the method by which the results are expressed. If from the resistance equations in Par. 75 the total car resistance is calculated for a number of car weights at the same speed, the resistances when plotted in relation to the weight as in Fig. 1 herewith give an irregular curve, which does not appear to be required by the experimental data, nor to express any special theoretical point. As a matter of fact, the quantity really measured in the first place was the total car resistance from which the resistance per ton was calculated. A

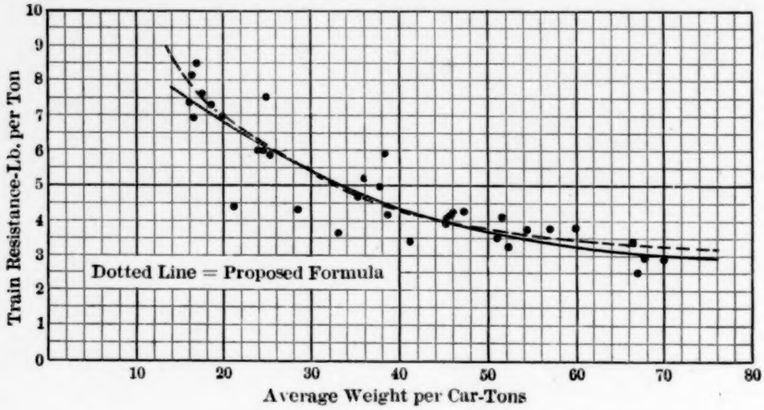


FIG 2 COMPARISON OF CURVES AT 5 MILES PER HOUR (FIG. 3 OF THE PAPER).

slight change in the coefficient of Par. 75 will be sufficient to make the change proposed. For general use, however, I would suggest the formula

$$R = 1.5 + \frac{106 + 2\,S}{W + 1} + 0.001S^2 \qquad [1]$$

where R is the resistance in pounds per ton of 2000 lb.
W is the weight of the car in tons
S is the speed in miles per hour

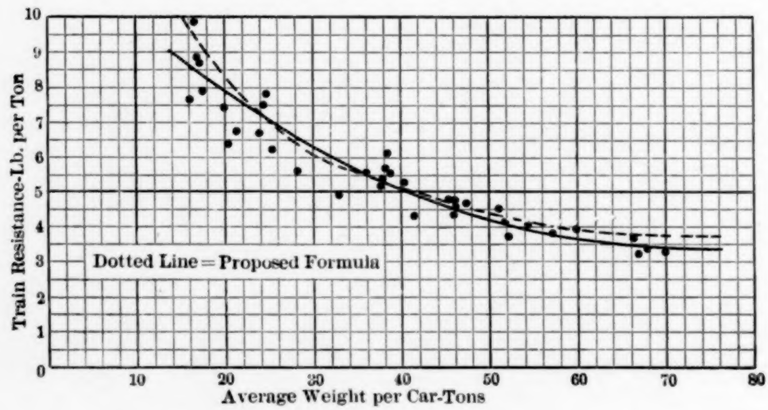


FIG. 3 COMPARISON OF CURVES AT 15 MILES PER HOUR (FIG. 5 OF THE PAPER).

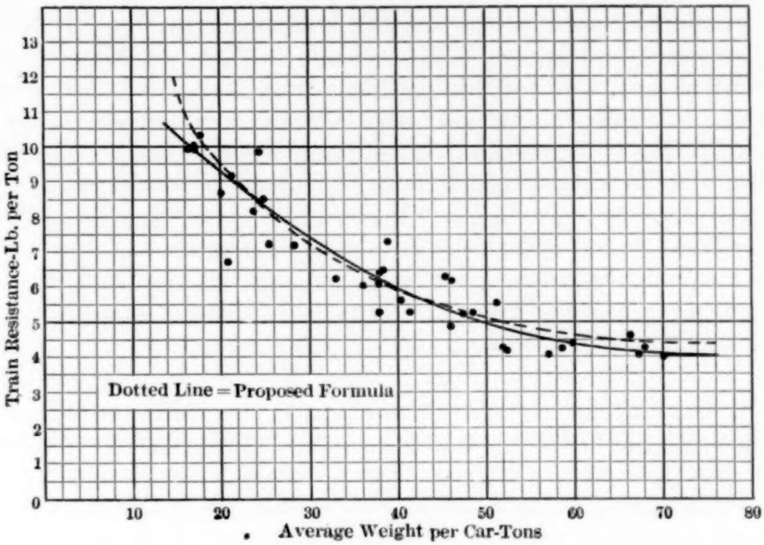


FIG. 4 COMPARISON OF CURVES AT 25 MILES PER HOUR
(FIG. 7 OF THE PAPER)

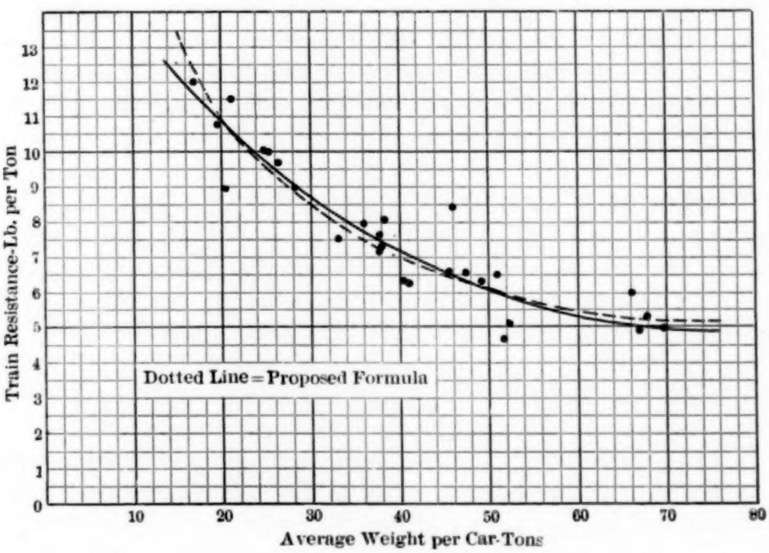


FIG. 5 COMPARISON OF CURVES AT 35 MILES PER HOUR
(FIG. 9 OF THE PAPER)

Formula 1 expresses quite closely Professor Schmidt's results for all combinations of weight and speed. To show the difference between the proposed formula and the original curves I have redrawn Figs. 3, 5, 7 and 9 of the paper (Fig. 2 to Fig. 5 herewith), adding in dotted lines the resistance given by the proposed formula. It will be seen that for all car weights down to 20 tons the two lines lie close together and that for lighter weights the new curve does no violence to the experimental data and gives figures which lie on the safe side of the original curves. The formula proposed is not offered as being more accurate than Professor Schmidt's, but simply as a more convenient form of expressing all of his results.

Robert Moore[1]. Professor Schmidt's paper presents for the first time, so far as I know, facts of great interest and suggests some very important conclusions. For example, it justifies very completely the general tendency toward heavier cars, the reasons for which have not been as well understood as they can be now.

2 I should like to know whether the author has worked out any theory as to the cause of this difference in the resistance of heavy and light cars. The high cost of handling freight in European countries is probably due to the use of cars so small that we could not afford to run them. Cars of the size that we send to the scrap heap are in regular use in Europe. This is an exceedingly valuable and suggestive paper and clearly points out the doom of the small car. The thanks of all engineers are due to those who have so clearly demonstrated that fact.

Charles Whiting Baker. This paper offers a great deal of food for thought to the engineer who is interested in traction matters. It shows that the resistance per ton for a loaded freight car is very much less than that for the same car when it is empty and is less for the modern 50-ton capacity car than for a light old-fashioned 10-ton car. This seems to indicate that to design a machine for small friction loss it is necessary to load the journal to the limit of safe practice and not to be content with light loads of 50 lb. per sq. in.

2 The difference in hauling capacity with different sized cars cannot be due to air resistance, because at the slow speed at which these tests were made this is very small.

[1] Consulting Engineer, Merchants Laclede Bldg., St. Louis, Mo.

Prof. H. Wade Hibbard. Examining the curves in Fig. 11 it will be noticed that at 15 miles per hour the resistance of the 75-ton car is $3\frac{1}{2}$ lb. per ton, while the resistance of the 15-ton car is nearly 9 lb. This difference is so great that the official who is charged with getting economic results from freight transportation should carefully consider the question of discarding small cars. When I was with the Lehigh Valley Railroad orders were issued to scrap certain small cars, of which we had many, as soon as they cost $16 for repairs. The application of engineering principles to the freight car will determine at what point the car ceases to earn its right to existence. The annual report of the Interstate Commerce Commission shows a great difference in the cost of hauling freight per ton mile on different roads. The Pittsburg and Lake Erie Railroad shows a very low cost per ton mile, due largely to the use of big cars and partly to the fact that they carry a heavy coal traffic northward to the lake and a heavy ore traffic southward to Pittsburg, thus hauling few empties.

2 A glance at the curves of Fig. 10 shows that they assume a horizontal aspect for a car weight of 75 tons, which seems to indicate that the 75-ton car is large enough and that an increase in weight would show little or no decrease in resistance. It is a very common practice among Americans to continue making things larger, but I am inclined to think from these curves that we have reached the limit of car size, as regards lessened tractive resistance per ton.

3 We are entering upon an era of scientific railroad engineering. We are getting out most thorough specifications and are applying engineering investigations to all sorts of mechanical equipment. The locomotive, for instance, is being born anew as an engineering structure through the efforts of trained engineers.

4 In my judgment heavy tonnage cars are easier to pull because they are made of steel and are very stiff over the truck centres, so that the trucks are free to swivel more easily when they are on curves and more readily take their natural positions on tangents.

5 Many years ago when Mr. J. W. Kendrick was with the Northern Pacific Railroad he had his road gone over with the dynamometer car for the purpose of adjusting locomotive ratings and consequent size of tranis. The result of adding a single car to each train would be a considerable increase in the productive capacity of any road.

6 It is not necessary for a road to go to the expense of a complete

dynamometer car such as Prof. Schmidt used. I have employed a hydraulic drawbar about four feet in length between the tender and train as a substitute and I believe that such an instrument will produce results and information of much value at a slight expense.

J. P. Clayton[1] mentioned the possibility of the curves in Fig. 10 turning upward again with heavier cars since they do not become isentropic in the last part of the curve as drawn.

F. W. Marquis. Professor Hibbard believes that we have reached the limit with a 75-ton car and I believe that this is true of the present design, but by increasing the bearing area the size of the car might be increased without increasing the resistance.

The Author. I have been especially interested in the formulae proposed by Dean Raymond, Mr. Fry, and Mr. Blood. While I believe that in the ordinary applications of the data the table is the most convenient expression of the results, I appreciate thoroughly the usefulness of such general formulae as have been proposed. The reasons for not including them in the original paper are set forth in Par. 74. Since, however, the discussion has brought forward suggestions for a general expression of the results in terms of R, S, and W, it seems well to present some of these which were deduced during the preparation of the manuscript. Among those which most accurately represent the experimental results are the following:

$$R = \frac{S + 41}{0.171\ W + 3.8} \qquad \text{(A)}$$

$$R = \left(1.5 + \frac{100}{W}\right)(1 + 0.01S + 0.0003S^2) \qquad \text{(B)}$$

$$R = \frac{41.6}{W^{\frac{3}{8}}}(1 + 0.01\ S + 0.0003S^2) \qquad \text{(C)}$$

2 Formula A gives a maximum deviation from the results of Table 3 of about 10 per cent when $W = 75$. For other values of W the error varies from $4\frac{1}{2}$ to $7\frac{1}{2}$ per cent. Formula B results in a maximum error of about 10 per cent, but this occurs when $W = 15$. For other values of W, formula B gives a maximum error of about 7 per cent. The maximum error resulting from the use of formula C at any part of its range is about 7 per cent.

[1] Assistant in Railway Engineering, University of Illinois, Urbana, Ill.

TWO PROPOSED UNITS OF POWER

BY PROF. WM. T. MAGRUDER, PUBLISHED IN THE JOURNAL FOR JUNE 1910

ABSTRACT OF PAPER

The paper gives a history of the terms "horsepower," "commercial horsepower," "Centennial horsepower," "unit of commercial evaporation," "unit of evaporation," "kal," "boiler horsepower," and shows how they have been changing in definition and value, with a comparison of the values in B. t.u. of the units of evaporation and of boiler horsepowers. An objection is made to the use of the term horsepower as applied to steam boilers, since as the output of a steam boiler is heat energy, it should be so measured. The capacity or power of a boiler and its output of energy should therefore be measured in "boiler-powers." A boiler-power is defined as 33,000 B.t.u. of heat energy delivered per hour by a steam boiler, steam main, hot-water heating main or the like, or added per hour to the feed-water of a boiler, or to the water of a hot-water heating system.

Similarly, an objection is raised to the term "horsepower" as the unit of measurement of the output of heat energy of a blast furnace, coke oven, gas producer, gas main or oil well. The statement is made that 10,000 B.t.u. of heat energy per hour are required for the development of a mechanical horsepower, as the average of the best gas engine practice today. It is proposed that the heat energies of gaseous and liquid fuels be measured in "gas-power," a gas-power being defined as 100,000 B.t.u. of heat energy delivered per hour by a gaseous or liquid fuel.

DISCUSSION

WILLIAM KENT. As one of those who took an active part in the establishment of the unit of boiler horsepower, as chairman of the Boiler Test Committee of 1884 and a member of the committee of 1889, it may be well that I should give my present views on the subject.

2 In the meetings of the committee of 1884 the question of the boiler-horsepower unit was thoroughly discussed. Among other units urgently favored by one or more members, but finally rejected, were the one now proposed by Professor Magruder, 33,000 heat units per hour; one proposed by myself, 30 lb. of water from and at 212 deg.; and one proposed by someone else, 30 lb. from 212 deg. into steam at 70 lb. pressure, which at that date was the unit adopted in specifications for contracts by the Babcock and Wilcox Company.

3 The unit adopted by the Centennial committee was 30 lb. of water evaporated into dry steam per hour from feed water at 100 deg. fahr., and under a pressure of 70 lb. per sq. in. above the atmosphere. The committee of 1884 adopted the same unit, but in order to express it both in terms of "from and at 212" and in heat units, they stated that it "shall be considered to be equal to 34½ units of evaporation, that is, to 34½ lb. of water evaporated from a feed water temperature of 212 deg. fahr. into steam at the same temperature. This standard is equal to 33,305 thermal units per hour." Taking the steam tables available in 1884, the total heat above 32 deg. of steam of 70-lb. gage pressure was 1778.24, and the total heat of water at 100 deg. was 68.08. The difference, 1110.16, divided by 965.7, the latent heat at 212 deg., gives 34.488 instead of 34.5. The product of 30 $\times$ 1110.16 is 33,304.8 thermal units.

4 The term "unit of commercial evaporation," quoted by Professor Magruder from the Centennial tests, and recalculated by him with different values in Par. 8, was not used by the committee of 1884 nor by the committee of 1889. It always was a useless unit, and there is no need of considering it now.

5 The committee of 1899, recognizing the facts that 100-deg. feed water and 70-lb. steam pressure no longer represented prevailing steam practice, as they did in 1876; that there was a general tendency to use the term "from and at 212 deg." in contracts for boilers; and that some scientific engineers wished to use the thermal unit in their calculations and reports, agreed to drop the condition of 100-deg. feed and 70-lb. pressure as the basis of the definition of the standard, and to take 34½ lb. from and at 212 deg. as the basis. This involved a recalculation of the heat units, which then became 33,317 instead of 33,305.

6 For the 33 years from 1876 to 1909 there has been no confusion or complication in the standard of boiler horsepower beyond the insignificant difference of 12 lb. in 33,300, and since 1899 there has been a universal acceptance of 34½ lb. from and at 212 deg. as the exact standard. The settled practice of 33 years, which has gone into the literature of steam boilers, and on which contracts are based, should not be changed without very strong reasons.

7 There is, however, a very good reason for changing the figures used in expressing boiler performance on a heat unit basis, and the factors of evaporation used for converting the evaporation under any stated condition into equivalent evaporation from and at 212 deg. It is that the old steam tables, based on the results of Regnault's

experiments of over 60 years ago, are now known to be slightly in error, and more accurate tables are now available. According to the new tables of Marks and Davis the latent heat of steam at 212 deg. is 970.4 B.t.u., and the heat equivalent of the boiler horsepower, or $34\frac{1}{2}$ units of evaporation, is 33,478.8 B.t.u. By Peabody's tables the corresponding values are 969.7 and 33,454.65, the difference being only about 0.07 per cent. This difference is due chiefly to the use of different values for the thermal unit, which according to Marks and Davis is $\frac{1}{180}$ of the heat needed to raise 1 lb. of water from the freezing point to the boiling point at mean atmospheric pressure, and according to Peabody is the heat needed to raise the temperature of 1 lb. of water from 62 to 63 deg. fahr.

8 The actual difference which arises from the use of the two tables may be shown by an example: Suppose a boiler evaporates 10,000 lb. of water per hour from 100 deg. fahr. into steam at 70 lb.-gage pressure, and uses 1000 lb. of combustible per hour, the heating value of the combustible being 15,000 B.t.u. per lb. Required the horsepower, the equivalent evaporation per pound of combustible, and the efficiency.

		Old Tables	Peabody	Marks and Davis
a	Total heat of 1 lb. of steam at 70.3-lb. gage	1178.3	1183.1	1183.4
b	Total heat of 1 lb. of water at 100 deg. fahr.	68.08	68.0	67.97
c	Difference	1109.22	1115.1	1115.43
d	Divide by latent heat at 212 deg.	965.7	969.7	970.4
e	Factor of evaporation	1.14862	1.14994	1.14945
f	Equivalent pound per hour from and at 212 deg.	11,486.2	11,499.4	11,494.5
g	Horsepower (equiv. evap. ÷ $34\frac{1}{2}$)	332.93	333.32	333.17
h	Heat units absorbed per pound combustible (c x 10) =	11,092.2	11,151.0	11,154.3
i	Efficiency, per cent. (h ÷ 15,000)	73.95	74.34	74.36

9 While the difference in the latent heat of steam at 212 deg. in the new tables is 0.07 per cent, the difference in the practical results is only about 0.04 per cent, since the total heats differ in the two tables.

10 The complication of which Professor Magruder complains will disappear if either one of the two new tables is used. There is no chance for confusion, misunderstanding, or "litigation between contractors on the accuracy of the fulfilment of the terms of a contract" if the contract defines a boiler horsepower as the equivalent evaporation of $34\frac{1}{2}$ lb. of water from and at 212 deg. fahr. and specifies that in

computing the equivalent evaporation Marks and Davis' or Peabody's table shall be used. If the tables are not specified, an engineer using the old tables might report the horsepower developed in a test as 332.93, while if he used Peabody's tables he would report it as 333.32, and if he used Marks and Davis' tables 333.17, scarcely a large enough difference to be the cause of litigation.

11 I prefer to use Marks and Davis' tables myself, because I think the heat unit upon which they are based, $\frac{1}{180}$ of the heat required to raise 1 lb. of water from the freezing point to the boiling point at atmospheric pressure, both of the points being those of physical phenomena which are independent of the graduations of a thermometer, is more capable of precise determination than the heat unit defined as the heat required to raise 1 lb. of water from 62 deg. to 63 deg. fahr. Other good reasons for the adoption of this unit are given in the preface to Marks and Davis' tables.

Edwin D. Dreyfus. Cases frequently arise in which comparisons must be made between a gas plant and a steam plant. Considering that in many installations there are different proportions of heat and power required, it becomes extremely important that we keep them on some rational basis, so as to avoid confusion. Inasmuch as we have definite standards for powers, we could consider the amount of energy delivered by the boiler or producer to the heat transferring medium, either steam or gas, as equivalent to so many heat units, in potential, sensible or latent heat; and then determine how much power could be developed from that heat, depending on the thermal efficiency of the steam or gas motor.

H. G. Stott. In discussing any unit of power it is always best to have a definite name for it. The names for units, especially electrical units, have all been given to prominent men who have made great research in the sciences or arts connected with electrical engineering.

2 It occurs to me that we have here an opportunity of perpetuating the name of a man, although he really does not require it because his name will always live in engineering science. Why not call this unit a "Thurston"?

3 It is proposed to reduce the horsepower from 33,479 B.t.u. per hr. according to Marks and Davis, to 33,000. The horsepower is irrational and empirical, while the kilowatt-hour, which is based upon the c.g.s. system, provides a rational unit. One kilowatt hour is

equal to 3412 B.t.u. Why not make a multiple of this quantity, 34,120 B.t.u., the unit for boilers and producers? This would raise the unit 641 B.t.u. instead of decreasing it by 479 B.t.u., as proposed by Professor Magruder. Dividing by ten would give a direct comparison of the efficiency from the steam or fuel to the switchboard.

I. LUNDGAARD.[1] A more striking example of chaos than the utter disorder and confusion that exist in the English system of technical units can hardly be conceived, and the most remarkable thing is that it is tolerated. What we need is not *more* but *fewer* units. There is a unit for heat; but that does not prevent us from having at the same time a unit of refrigeration, a unit of evaporation, a boiler horsepower; and the paper under discussion proposes a boiler-power, and a gas-power.

3 Manifestly we should have no unit of heat, since heat is energy, and the unit of energy is directly applicable. We would then save the conversion of British thermal units to foot pounds for calculations of efficiencies of heat cycles. But energy is measured in foot pounds and horsepower-hours, so we have the same multiplicity of units in this case.

4 The paper under discussion is unfortunate both in its aim and in the selection of the names of the new units. The two proposed units are unnecessary, and they add another calculation to our labors and are therefore harmful. They convey no familiar impression or resemblance to our minds that would facilitate their comprehension and remembrance. Until we adopt some better units, let us use the British thermal unit; or, in cases where this unit is too small or too large, let us use some decimal part of it.

THE AUTHOR. I quite agree with Mr. Kent that standards should not be changed except for very strong reasons. But he proposes to change again the standard for a boiler horsepower to suit the new steam tables and the new definition of a British thermal unit as proposed on page 6 of Marks & Davis' steam tables. Mr. Kent loses sight of the fact that I am not proposing a change in the definition and value of the boiler horsepower, as he does, but rather a more logically named unit and a fixed value for it which will not have to be changed with each new investigation on the heat of water and steam, to be called a "boiler-power" rather than a "boiler-horse-

[1]Associate Engineer, Rochester Railway and Light Co., Rochester, N. Y.

power." I propose to substitute the use of the term "boiler-power" for the term "boiler-horsepower," the former being definite and fixed and the latter being variable in value.

2 Accepting Mr. Kent's example, it will be seen that a difference of 0.41 per cent in the efficiency of a boiler as calculated by the old tables (73.95 per cent) as compared with its efficiency as calculated by either of the later steam tables (74.34 per cent or 74.36 per cent) is enough to cause misunderstanding. The use of the British thermal unit, or its multiple, in all commercial and scientific measurements of the heat absorbed and given out by a boiler would free us from the complications incident to "from and at."

3 If we accept Mr. Stott's suggestion that a "Thurston" is 34,120 B.t.u. of heat energy delivered per hour by a boiler, let us add that an "Otto" is 10,000 B.t.u. of heat energy delivered per hour by a gaseous or liquid fuel.

4 I cannot agree with Mr. Lundgaard in his statement that we should have no unit of heat, but should measure it solely in foot-pounds, simply because "heat is energy." As electricity is another form of energy, would he require us to measure the capacities and outputs of dynamo machinery in foot-pounds rather than in joules and watts? However, I agree with his conculsion to use the British thermal unit and multiples of it, and therefore proposed 10,000 B.t.u. per hour as one gas-power, and 33,000 B.t.u. per hour as one boiler-power. The object in writing this paper was not to increase the number and complexity of the units already in existence, but to simplify the units of capacity, or output, of steam boilers and gas-producers before a more complex and irrational unit shall become fixed by use for the latter.

OPERATING EXPERIENCES WITH A BLAST FURNACE GAS POWER PLANT

By H. J. Freyn, Published in The Journal for June 1910

ABSTRACT OF PAPER

The plant under discussion in the paper consists of four 2000-kw. gas engine generators receiving blast furnace gas cleaned in a preliminary and a secondary washing plant. The former consists of two tangential dry dust catchers and two wet scrubbers, or hurdle washers, while in the latter plant Theisen gas washers are used. The gas supplied by six blast furnaces, had in 1909 an average heat value of 98.3 B.t.u. per cu. ft., and contained 26.51% CO, 3.57% H, and 0.196% CH_4. The temperature of the gas entering the gas-cleaning plant averaged 332.5 deg. fahr., which was reduced during the cleaning process practically to atmospheric temperature at the engines. The average raw gas pressure was 9.29 in. of water, while gas of 4-in. pressure was delivered by a 100,000-cu. ft. gas holder. The average amount of flue dust in the dry-cleaned gas was 1.53 grains per cu. ft., which during the washing process was reduced to 0.0058 grains per cu. ft. The wet scrubbers took out 80% and the secondary cleaning plant 98% of the amount of dust received. The total efficiency of the gas-washing plant was 99.5%. The amount of moisture in the engine gas averaged 5.62 grains, against 3.49 grains in the atmospheric air. The amount of water used for gas cleaning averaged 102 gal. per 1000 cu. ft. of gas cleaned, 83 gal. of which was used in the wet scrubbers, and 19 gal. in the Theisen washers. The power consumed in the gas-cleaning plant was 3.3% of the gas engine output. The load factor for the year was 72%, and the average running time was 77% of the total possible time. The thermal efficiency of the plant at the engine shaft, as determined continuously by Venturi meter, averaged 20.8% for 1909. The total output of the station was 50,494,100 kw.

ADDITION

The following addition to his paper was given orally by Mr. Freyn in presenting it before the Society at the Spring Meeting and should therefore be considered a part of his paper.—Editor.

APPENDIX No. 6

SUMMARY OF OPERATING RESULTS DURING THE FIRST FOUR MONTHS OF 1910

In January 1910, the first gas blowing engine was started very successfully, and since that time two more have been put in operation, furnishing blast to three furnaces. One of these engines is blowing blast furnace No. 4 without the aid of steam blowing engines, delivering 40,000 cu. ft. of air per minute.

2 The change in the arrangement of the preliminary gas cleaning plant mentioned in the paper was put into effect in January and the results obtained by operating four wet scrubbers in parallel are very satisfactory.

3 The addition of gas-blowing engines and the larger output of the gas-electric station has very materially increased the quantity of power gas consumed, so that at present about 27,500 cu. ft. of gas are being purified each minute with four gas-electric and three gas blowing engines in operation. The average quantity of gas cleaned per minute for the first four months of 1910 was 20,845 cu. ft. or about 25% more than the average for the year 1909 and 46% more than the corresponding average from January to April 1909.

4 Inasmuch as five blast furnaces have been in operation since the beginning of the year, and since gas blowing engines are supplying a large percentage of the blast to these furnaces, the gas supply has always been more than sufficient, the surplus gas being utilized at present to fire the boilers at the adjacent plate mill, which heretofore had been fired with coal.

5 The average output of the gas power plant for the first four months of 1910 was 5663 kw., corresponding to a load factor of 70.8%. The average time of operation of the plant for this period was 557 hours per month or 77.5% of the total possible time. Repairs on the engines were responsible for 17.5%, while operation of the plant caused 5% of the shutdowns. In no instance was lack of gas responsible for lost time during this period. The gas pressure of the raw blast furnace gas averaged 10.6 in. of water, while the average gas pressure after the secondary washers was 14.9 in.

6 Under present conditions, with blast furnace No. 1 out of blast and the plate mill boiler house receiving gas, the bulk of the gas for the engines is being furnished by furnace No. 3. This was most strikingly proved a few weeks ago, when for certain operating reasons the watering of the stock on this furnace was abandoned. The consequence was a tremendous increase in the amount of flue dust carried into the gas cleaning plant, which became so serious that the watering of the stock on this furnace had to be resumed. Since furnace operation during this period was remarkably smooth and uniform no difficulties or troubles were encountered in the operation of the gas engines from backfiring and premature explosions, nor did sudden changes in the quality of the gas occur.

7 The average composition of the blast furnace gas delivered to the engines for the first four months of 1910 was 14.8% CO_2, 25% CO, 3.59% H and 0.22% CH_4, with a computed heat value of 93.15 B.t.u. and a heat value of 92.9 B.t.u. per cu. ft. determined by calorimeter. The ratio $\frac{CO}{CO_2}$ was 1.69, materially lower than for the corresponding period of 1909, when it was 2.1, indicating low coke consumption and a more rational operation of the furnaces.

8 The average temperature of the gas entering the gas cleaning plant was 255 deg. and 84 deg. before the wet scrubbers. The reduction in temperature due to radiation through the unlined zigzag flue was therefore 67% in 1910 against 66.6% for the corresponding period of 1909, the average air temperature being 40 deg.

9 Since the velocity of the gas traveling through the pipes is materially greater on account of the larger quantity of gas purified, only small quantities of flue dust are being deposited in the dust legs of the zigzag flue and the gas delivered to the wet scrubbing plant is considerably dirtier than it was last year. The amount of flue dust in dry cleaned gas averaged 1.8061 grains per cu. ft. with a minimum of 1.3979 grains in January and a maximum of 2.3361 grains in April. The wet scrubbers, only two of which were operating in series up to May 1910, removed from the gas an average of 91.5% of the flue dust, delivering clean gas containing an average of 0.1488 grains per cu. ft. This high efficiency of the wet scrubbers is maintained with four scrubbers operating in parallel. With over 27,000 cu. ft. of gas cleaned per minute, the four wet scrubbers have removed in May 1910, an average of 96.1% of the impurities received. The average temperature of the clean gas delivered to the Theisen washers was 52 deg., the gas entering the gas holder at 50.55 deg. These temperatures were lower than the temperature of the water supply, 55.41 deg., since the average air temperature did not exceed 40 deg. for the first four months of the current year. The temperature of the waste water from the first wet scrubber was 86.85 deg. on account of the larger quantity of gas passing per minute, and the temperature of the waste water from the second scrubber, 56.38 deg., was only a little higher than the temperature of the water supply, proving that the cooling effect took place almost exclusively in the first wet scrubber.

10 The amount of moisture in the clean gas was 4.735 grains per cu. ft. and the fine gas carried 3.658 grains against 1.994 grains of moisture in the atmospheric air. The larger amount of moisture in 1910 is due to the reduced water consumption and to the larger quantity of gas purified per minute, which reduced the time during which the cooling and condensing effect of the water and the atmosphere acted on the gas.

11 The efficiency of the secondary cleaning plant was over 96%, with a minimum of 95% and a maximum of 97% in January and April respectively. The amount of flue dust in the fine gas averaged 0.00632 gr. per cu. ft., being 9% higher than the average for the whole year of 1909, while the amount of gas cleaned per minute was 25% larger. It is to be noted that the overall efficiency of the wet scrubbing and secondary cleaning plants for this period was 99.6%, so that only 0.4% of the amount of dust originally contained in the dry cleaned gas was carried over into the gas engines.

12 The quantity of water used in the Theisen washers averaged 17.5 gal. per 1000 cu. ft. of gas cleaned or about two gallons less than the average for the

whole year of 1909. A marked economy in the amount of water used in the wet scrubbers was realized, only 63.1 gal. of water being supplied per 1000 cu. ft. of gas cleaned. The reduction in the total water consumption amounted therefore to more than 20% compared with 1909, and a further reduction is being tried at present, since it was found that with four wet scrubbers operating in parallel the clean gas is relatively cleaner than it was with series washing in two wet scrubbers.

13 Unfortunately the power consumption, and therefore the cost of cleaning per unit of gas will not be very much affected by such a reduction, since the wet scrubber pumps do not use more than about 10% of the total amount of power consumed in the gas cleaning plant.

14 The average power consumption for the first four months of 1910 was 0.308% for the wet scrubber pumps, 3.011% for the Theisen washers, the total being 3.319% of the combined output of all gas engines.

15 The heat consumption of the gas-electric station with an average load of 91.45% on the engines while in operation was 16,873 B.t.u. per kw.-hr. or, at 96.2% generator efficiency, 12,101 B.t.u. per b.h.p.-hr., so that the average thermal efficiency at the shaft for the first four months was 21.1%. The averages for the individual months were 20.9%, 21.9%, 20.8% and 20.8% respectively.

16 While it has not yet been possible to determine the thermal efficiency of the various types of gas blowing engines recently installed, Venturi meter measurements of the total quantity of gas delivered to the gas holder indicate that the heat consumption of the three engines operating at about 70% of their full load capacity averages about 12,000 B.t.u. per b.h.p-hr., these engines operating at about 70% of their full load capacity. The thermal efficiency of the plant is therefore about 21%. The result of the fuel economy of the gas-blowing engines is a very marked reduction in coal consumption of the plants which are directly or indirectly benefited by the installation of these engines.

DISCUSSION

A. E. Maccoun.[1] Mr. Freyn's statement regarding the excess power from blast furnaces is, I think, a little excessive. Where blast furnace plants are connected with steel works, requiring all their excess power, or are in such locations that they can dispose of their surplus power at a profit, there should be no hesitancy in installing gas engines for at least 85 per cent of the power required in blowing the furnaces and for generating electricity for use at the works or for transmission, but in some cases blast furnaces are not so ideally located. On account of the higher cost of gas-engine installations over those of steam, under such conditions the former naturally could not be recommended. All conditions of this kind should be carefully studied, as in many cases gas-engine installations may be carried too far.

[1] Superintendent of Furnaces, Carnegie Steel Company, Braddock, Pa.

2 I fully agree with Mr. Freyn in not trusting to automatic arrangements for regulating the gas supply, as the gas pressure must necessarily be kept up in any gas system to insure safety. If the gas pressure falls below that of the atmosphere and air enters, there is always great danger of a very serious explosion.

3 We have noticed practically the same condition Mr. Freyn refers to in regard to getting, at times, a supply of ferro-silicon gas, spiegel gas, or ferro-manganese gas at the gas engine in case a furnace on one of these products happens to have its gas entering the main in the vicinity of the gas-washer intake. At the Edgar Thomson plant there are eleven furnaces connected to one gas main, but the different gases seem to equalize themselves in the main according to their pressures, and the quality of gas depends on where it is taken from the main.

4 All blast-furnace gas-engine plants have had more or less experience with back-firing, especially when they are making special grades of iron, such as ferro-silicon, spiegel, etc. The inlet valves of the engine should be designed so that where this occurs for long periods, endangering operations, the relative areas of the gas and air ports can be changed quickly by hand while the engine is in operation between the limits of 1 unit of air to 4 of gas, and vice versa.

5 The discrepancies in the heat values are accounted for by the fact that analyses are made about every three hours, while calorimeter readings are taken almost continuously. Some time ago we had occasion to make an average of 168 gas analyses during one of our tests on a furnace running on 1927 lb. of coke per ton of iron. The results were: $CO_2 = 16.33$ per cent, $CO = 22.73$ per cent, $H = 1.99$ per cent, $CH_4 = 0.04$ per cent, $N = 58.91$ per cent. The calculated heat value per cu. ft. of this gas at 62 deg. fahr. and 30 in. mercury was 80.55 B.t.u. From approximately the same number of Junker calorimeter readings taken at the same time the result was 75.84 B.t.u.'s per cu. ft. The gas from a blast furnace frequently contains over 24 grains of moisture per cu. ft. When the analyses are made it is customary to get the percentage of the different constitutents by volume, excepting the moisture it contains. When the gas is cooled before making the determinations, a large percentage of the moisture is condensed, and by not making allowance for this moisture the gas is figured as of slightly higher thermal value than it actually is. The thermal readings from the calorimeter are usually considered more accurate than those figured from analyses.

6 All of the gas-washing plants for gas engines that have been

installed in this country have been very successful, so far as I know, although I think some of them were built on a more elaborate scale than necessary, merely to be sure that the gas would be thoroughly cleaned. In nearly all the gas-washing plants I am familiar with, the amount of dirt in the gas after washing was found to be less than that in the air. Extra precautions were naturally taken in designing our first gas-washing plants on account of the large percentage of fine ores that usually compose our blast furnace burdens, but in every case the gas cleaning was found to be very thorough.

7 Blast furnace gas, like any other gas, has a saturation point for moisture, depending on its temperature. If it is cooled down low enough it can only contain a fixed amount of moisture, depending on its saturation point, except the moisture which is mechanically contained, and any such moisture is very easily removed with a few baffles in the gas flue. Elaborate dryers are not usually required.

8 The thermal efficiencies for the gas-engine plant of approximately 23 per cent are all that could be expected under the conditions. Higher values have been obtained in tests, but for continuous work the plant efficiencies obtained by Mr. Freyn are very creditable.

9 *Gas Engine Development.* As Mr. Freyn states, the Lackawanna Steel Company was the first to attempt a large blast furnace gas engine installation in this country. They adopted the two-cycle Koerting engine, built in this country from German designs. The United States Steel Corporation decided in 1904 on an initial installation of blast furnace gas engines at the Edgar Thomson furnaces of the Carnegie Steel Company, which was followed by other installations. After a thorough investigation of the various types of engines used abroad the officials of this company decided that the four-cycle gas engine would be best adapted for their use, and that in designing such an engine the lines and construction of the modern heavy-duty American steam engine should be followed as nearly as possible, as this type of engine had proved universally successful. They also endeavored in the design of these gas engines to eliminate as many complications as possible and to arrange all parts so as to be easily accessible for removal and replacement. All the firms starting to build blast furnace gas engines in this country at the time preferred the center-crank construction in place of the American side-crank construction which has proved itself so successful and convenient. It was decided that an over-hung crank gas engine could be made strong enough and that these engines should be of this type. The heavy American rolling-mill engine frame was also insisted upon. The

Westinghouse Machine Company, in coöperation with the engineers of the Carnegie Steel Company, designed our first engines along these lines.

10 The Snow Steam Pump Works, the Allis-Chalmers Company, and others who were starting into the blast furnace gas-engine business also realized the importance of building along American lines and should be mentioned in connection with the development of a successful gas engine suitable for American blast furnace and steel works practice. I do not mean to detract in any way from what our friends abroad have done in developing the gas engine, as we are greatly indebted to them. It required a great deal of courage to go into this business on such a large scale, knowing that these engines would have to prove just as reliable prime movers as modern American steam engines, which have been years in reaching their present state of perfection.

11 The Carnegie Steel Company had built a small tandem gas engine, $21\frac{3}{4}$-in. diameter cylinders and 30-in. stroke, as nearly along the designs of the larger units as possible. This engine and a 250 h.p. direct-current generator were temporarily installed for experimental purposes at the Edgar Thomson furnaces and were started December 9, 1905. This unit was run continuously under all kinds of conditions and numerous tests were made on it. The information acquired from this experimental engine helped in perfecting the designs of the larger units.

12 *Different Systems of Governing.* At that time it was a great question as to whether a gas engine should be governed by the constant-mixture system or by the constant-compression system. The constant-mixture system, brought to so much prominence by Mess in Germany, consists of governing the mixture of air and gas admitted to the cylinders so as to have an explosive mixture that will readily ignite at all loads, although on light loads the compression must necessarily be greatly reduced.

13 The constant-compression system consists in admitting an excess of air into the cylinder with the amount of gas required for any particular load, so that on light loads nearly the same compression will take place as on heavy loads. Efforts were made to stratify this mixture in the vicinity of the igniters so that it would readily ignite on light loads. To effect this stratification many complications were necessarily resorted to.

14 A trial of the constant-compression system proved that when there was no load the charge could not be depended upon to burn and

that at other loads the indicator cards showed a marked difference in area from one explosion to the next at exactly the same load. The full-load cards were the only ones to reach the proper shape. These conditions are characteristic of this type of governing and are due to imperfect combustion at loads under the full rated load of the engine. With the constant-mixture system, however, the cards were of proper shape at all loads, and of the same area for equal

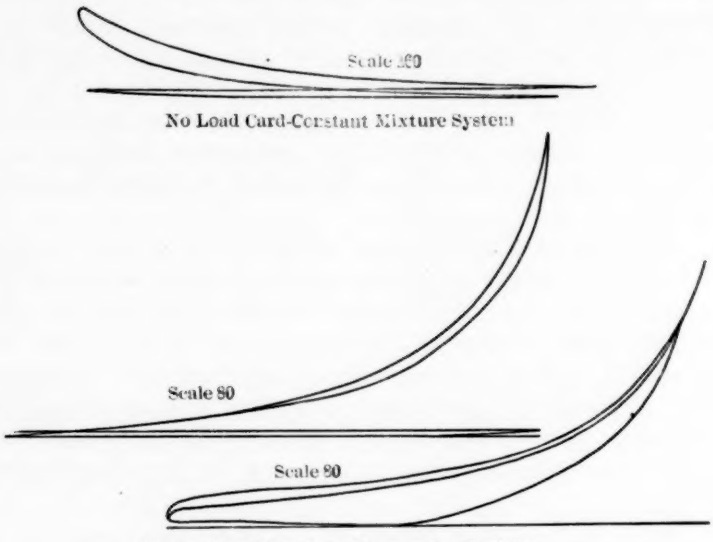


FIG. 1 COMPARISON OF CONSTANT-MIXTURE AND CONSTANT-COMPRESSION CARDS TAKEN AT NO LOAD

THE TWO LOWER CARDS SHOW THE UNCERTAINTY OF THE CHARGE BURNING AT NO LOAD WITH THE CONSTANT-COMPRESSION SYSTEM. IN ONE CASE THE AREA IS NEGATIVE AND REPRESENTS ONLY THE COMPRESSION LOSS DUE TO A POSSIBLE LEAK. WHILE THE OTHER HAS A POSITIVE AREA, THE COMBUSTION IS NOT WELL TIMED. THESE CARDS WERE SELECTED AT RANDOM FROM A LARGE NUMBER.

loads. (Figs. 1, 3 and 4). Continuous indicator cards showed absence of misfiring at no load and with a compression not over 65 lb.[1]

15 From the small experimental engine which helped to demonstrate these points, it was found that on light loads with constant compression the charge would not ignite for periods, the engine

[1]Continuous cards were submitted with the discussion which have not been reproduced for publication.—EDITOR.

would slow down slightly, then take a large gulp of gas and air and fire for a short period and so on, so that it could not be depended upon when light or extremely variable loads were being carried.

16 We therefore adopted the constant-mixture system and have obtained excellent results. It may not be quite as refined and economical as the constant-compression system, but it is better suited for this class of work, particularly on variable loads, although under some conditions excellent results are no doubt obtained with the latter.

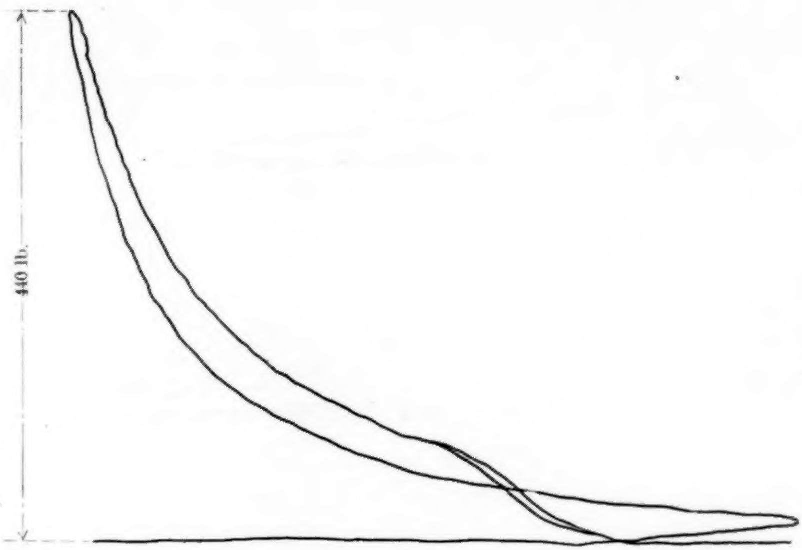


Fig. 2 Indicator Card showing Pre-Ignition, resulting in a Pressure of nearly 500 lb. per sq. in.

Card shown full size; scale of spring 160; maximum cylinder pressure recorded.

17 It does not seem natural, especially with a four-cycle gas engine, to draw in a very lean mixture of air and gas, compress it to the usual full-load pressure of 200 lb. into a comparatively small volume, and then expect to have the mixture stratified in the vicinity of the igniters so that it can easily be exploded.

18 *Gas Engine Operation.* The installation of gas engines at the Edgar Thomson furnaces consisted of two Westinghouse twin-tandem gas blowing engines, 38-in. diameter and 54-in. stroke, and one Westinghouse twin-tandem unit, 40-in. diameter and 54-in. stroke, for driving a 1500-kw. generator. The first blowing engine was started

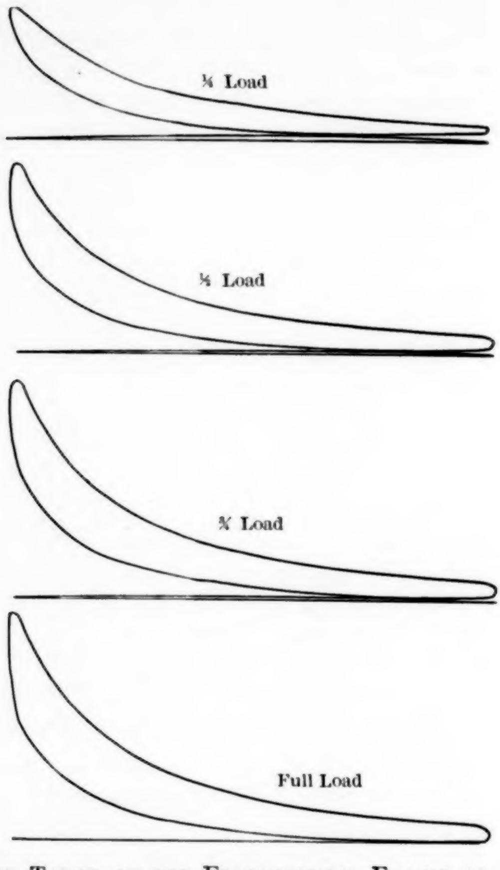
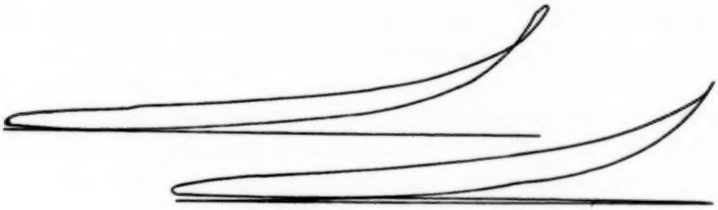
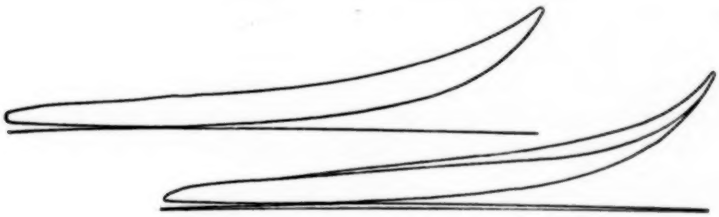


FIG. 3 CARDS TAKEN ON THE EXPERIMENTAL ENGINE OF THE CARNEGIE STEEL COMPANY, WHEN OPERATING ON THE CONSTANT-MIXTURE SYSTEM.

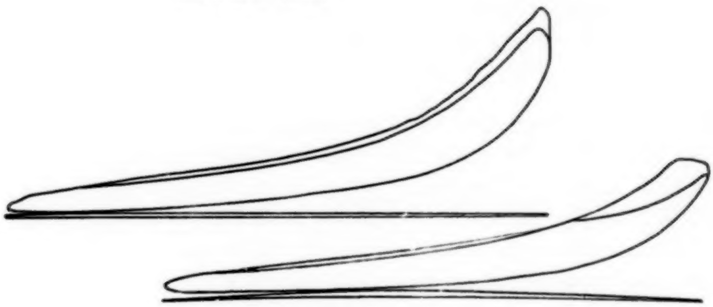
THESE ARE TO BE COMPARED WITH THE CONSTANT COMPRESSION CARDS SHOWN IN FIG. 4. IN BOTH SERIES THE LOADS WERE MAINTAINED CONSTANT AT THE DIFFERENT PERIODS. IT WILL BE NOTED THAT THE AREAS OF THE CONSTANT-COMPRESSION CARDS VARY FROM ONE EXPLOSION TO ANOTHER AND THAT THOSE TAKEN AT FULL LOAD WERE THE FIRST TO REACH THE PROPER SHAPE. THIS IS DUE TO THE IMPERFECT COMBUSTION AT ALL LOADS UNDER THE FULL OR RATED LOAD, A CHARACTERISTIC OF THIS SYSTEM OF GOVERNING.



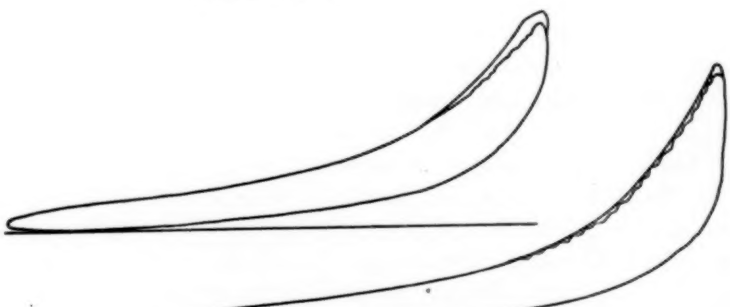
Cards at ¼ Load



Cards at ½ Load



Cards at ¾ Load



Cards at Full Load

FIG. 4 CARDS FROM THE EXPERIMENTAL ENGINE TAKEN ON THE CONSTANT-COMPRESSION SYSTEM.

on December 7, 1906, and the others followed soon afterwards. From the operation of these engines and from many others that have since been installed, much valuable information was acquired and many improvements in design have followed. All the difficulties encountered since the starting of this plant have been met and overcome and in 1909, No. 1 blowing engine ran 8241 hours out of 8760, or 94 per cent of the time; No. 2 blowing engine ran 8186 hours out of 8760, or 93.5 per cent of the time; and No. 1 electric engine ran 7075 hours out of 8760, or 81 per cent of the time. I would consider these records very good even for the best type of steam engines.

19 *Lubrication.* Great care should be exercised in selecting proper gas-engine cylinder oil and the oil used should be carefully tested. An oil showing the following analysis has been found to be very satisfactory:

Specific viscosity (compared to water) .	4.10
Flash point, deg. fahr..	530
Burning point, deg. fahr.	600
Deg. Baume (Sp. Gr. 0.880)	28

20 An important test can be made by filtering oil through filter paper, to see if there is any carbon deposit in the oil. This is often due to the temperature of distillation being too high, or to the distillation being carried too far, or to the imperfect filtration of oils that have been heated too high. Such oils will frequently break up and deposit carbon, rendering the oil utterly unsuitable for gas engine use. It is unnecessary to say that a paraffin base oil should be used and never one with a tar base.

21 Our method of oiling cylinders is to pump the oil in when the crank is 50 deg. early of the forward center-line on the suction stroke. There are two oil holes on each end of each cylinder, 30 deg. on each side of the centre. With this arrangement the oil runs down the cylinder walls and is wiped over by the piston.

22 *Ignition Systems.* Mechanical make-and-break and electrical make-and-break ignition systems are used and both work very satisfactorily, but as much care as possible should be taken to make an even distribution of the igniters around the cylinders.

23 Indicator cards taken with one, two and three igniters working show plainly the better efficiency obtained with three igniters in operation. With blast-furnace gas it takes time for an explosion to propagate. This is plainly shown by our being compelled to have the igniters fire from 30 to 35 deg. before the crank pin passes its centre.

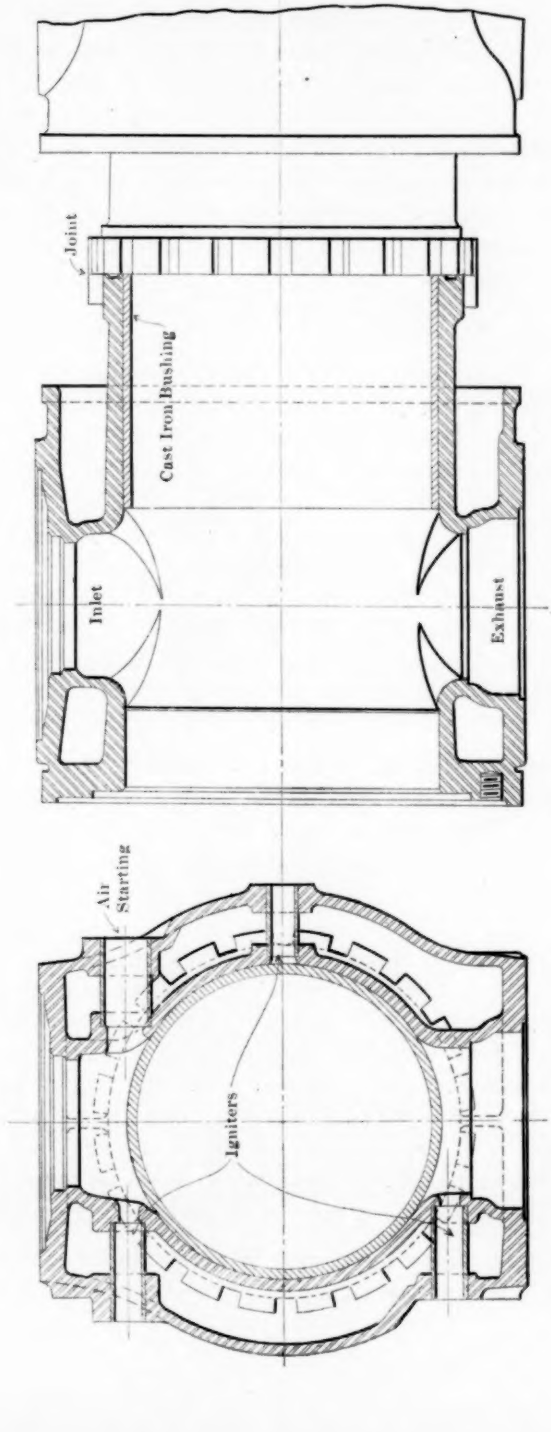


Fig. 5 Cast-Steel Cylinder for 40-in. by 54-in. Gas Engines

If the igniters are all on top of the cylinder, or all on the sides or bottom, most of the wear is on these points, due to the explosion pressure getting under the rings sooner and being greater at these points.

24 *Gas Engine Conditions.* As is well known, the very high explosive pressure at the beginning of the piston stroke subjects the pistons and ends of the cylinders and cylinder heads to severe pressure and temperature conditions, requiring them to be carefully water jacketed and designed to take care of expansion. A blast furnace gas engine, even with these high explosive pressures, rarely averages over 65 lb. m.e.p. in the cylinders.

25 In Fig. 2 is an indicator card showing preignition. The pressure is nearly 500 lb. per sq. in. and in some cases these preignition pressures might be higher. With a 44-in. diameter piston it can be seen that while the explosive pressure continuously transmitted through the working parts of the engine is always large, an additional pressure of 1,000,000 lb. may suddenly be put on the crank pins by preignition. This is why many difficulties such as cracked pistons, heads and cylinders, lubrication troubles, etc., have been encountered, especially on the larger size gas engines. These difficulties, however, are all being overcome and high-class gas engines of large power have been the result.

26 *Gas Engine Cylinders, Pistons and Heads.* The proper water cooling of cylinders, pistons and heads is very important, especially for large engines. The cylinders should have ample waterjacket space between the main cylinder and the outer water jacket should be well fitted with hand holes so that mud deposits can be thoroughly cleaned out.

27 Fig. 5 shows the design of a cast-steel gas-engine cylinder. It has been the aim to make this as simple a casting as possible. The ends next to the explosion were cast down so as to get the best material in that part of the cylinder. It has usually been the practice to make these cylinders of cast iron and with this construction large cylinders required walls approximately $4\frac{1}{2}$ in. thick to resist the heavy explosive pressures. The cylinder shown is of cast steel, bushed with a 1-in. cast-iron bushing, arranged so as to be free to expand lengthwise. This bushing can also be easily removed and replaced.

28 The cast-steel cylinder construction permits us to decrease the thickness of the cylinder walls without decreasing the strength through the cylinder. By this means the water cooling can penetrate much closer to the hot cylinder walls, thus drawing the heat from these vital parts and preventing fatigue of the metal at each end of the cylinder where the heavy explosions take place. This fatigue of the cylinder metal is still more pronounced on gas engines operating on some of the richer gases.

29 There have been some difficulties due to the cracking of gas-engine pistons and cylinder heads, but usually these have been caused by omitting to make the proper provisions for the increased strains and temperature conditions which they are required to stand. In most cases the pistons and heads are now made from cast steel for the larger size gas engines, which permits lighter walls and much more effective water cooling.

30 In all cases the weight of pistons and rods of gas engines should be carried on the crosshead and slippers. The pistons should have at least $\frac{1}{16}$-in. clearance all around the bore of the cylinder, thus leaving only the friction of the piston rings on the cylinder. These rings should be fairly wide and deep and held in place by good strong springs and keepers.

31 Since our engines have been in operation there has been only one case where we have cut a cylinder, and this was due to a water leak.

Joseph Morgan. The Cambria Steel Company has made a small beginning with one gas engine to determine the best way of purifying the gas and also to determine a good type of blowing engine. There is always an experience account in operating plants, which commenced with us when we blew in our No. 7 blast furnace. On the design of an engineer of large experience, we had provided two down-comers for the furnace, each with a large dust-catcher. These dust-catchers were of the usual shape, about 22 ft. in diameter in the cylindrical part, with a cone top and bottom and a fairly large cubic capacity. The down-comer originally entered radially into the cylindrical part pointing downward, at about the same angle as the bottom cone. The gas to boilers and stoves was taken off at the top of the upper cone, and we relied on the large capacity of the two dust-catchers to allow a settlement of the heavy dust to the bottom of the cone, but somewhat to our surprise we got very little dust from the dust discharge openings and very great quantities of dust in the stoves and boiler chambers.

The cause was the action of the heavy volume of gas entering the chamber which, being directed to the center and downward, kept the dirt stirred up from the bottom cone and allowed no settlement. At the first stoppage of the furnace we changed the entrance of the down-comers to a tangential connection in a nearly horizontal direction into the upper part of the cylinder, with the result that the dust caught was largely increased. We also added brick cross-walls on the bottom cone, so that the discharge opening was not closed, but which prevented a current of gas in the bottom cone from stirring up the dust. The dust that came down into the bottom cone was caught in this lower chamber. This detail added to the efficiency of the dry dust-catcher. The resulting increase of efficiency was a valuable lesson on the effect of centrifugal force in separating dust, and the necessity of keeping the gas currents from stirring it up again. In recent improvements on several furnaces we have also added in series with and also following the first dust-catchers, a horizontal dust separator in which the principle of dry centrifugal separation is made use of. We have this apparatus at work on two furnaces, one of which supplies our gas engine.

2 This horizontal separator contains a helical gas-passage through which the gas flows. Each turn of the helix has at its bottom a dust-trap so that the dust carried by the centrifugal force to the outside of the helix goes tangentially into the traps from which it is drawn when necessary. This helical separator traps about ten to fifteen tons daily in addition to that stopped by the large dust-catchers and takes out about 70% of the dust remaining in the gas after leaving the first dust-catcher. The indications are that five or six helical turns are sufficient.

3 This completes the dry separation, which in our plant it is desirable for reasons of cost to make as complete as possible without the use of water, as the dust runs freely from dust-pockets when dry and is therefore handled more cheaply. In our earlier experience we tried several types of wet separators near the furnace, but the great volume of wet dust added largely to the cost of handling. We believe the large quantity of very heavy dust should be taken out as far as possible by dry separation, and that water should be used after the gas has somewhat cooled by radiation. This lessens the quantity of water necessary for final cooling and is another economy.

4 From this separator the gas is taken direct to the stoves and boilers, but for the experimental gas engine we have installed a pair of Schwartz revolving centrifugal washers, somewhat similar to the

Theisen, which are used in series. The water comes out from the first very muddy, while from the second it is very limpid, showing that the former takes out most of the dirt, and the latter perfects the operation. This is perhaps a temporary arrangement, as we have no static cleaners other than the dry dust-catchers or cleaners already described.

5 The engine under trial at our furnace is a double, horizontal, tandem gas-engine with four gas and two blast cylinders, built by the Southwark Foundry Company of Philadelphia. It is novel in several details, all of which have proved of value on trial, as adding to the speed of running and the ease of manipulation. The blowing cylinders are fitted with gridiron slide valves of the well-known Southwark type for inlet and outlet of blast. All the valves for both air and gas cylinders are actuated by the straight-bar reciprocating cam of Southwark type, which allows great facility for adjustment of the cam not found in arrangements of those on rotary shafts. The engine can easily be run at 70 revolutions, a much greater speed than is attainable with ordinary blast valves. This lessens the cost of engine installation or increases the quantity of available air from a cylinder.

6 In addition, there is a tripping device by which the blast inlet valves at one or more of the four ends of the blowing cylinders may be put out of action and left open, thus partly or wholly unloading the engine in starting up or when the furnace needs less blast or even none. This greatly facilitates the starting and manœuvering of the engine, as it need not be started under load or be stopped at casting times or to slacken blast.

7 The other departure from former designs is in the gas-entrance and exhaust valves. The gas cut-off valves located on top of the cylinders are tripped by the action of magnets, the current for operating which is timed by the governor action. The exhaust valves are located so that they are very conveniently accessible, being at the side of the cylinder and above the floor instead of under the floor, as in many gas engines heretofore built. This has been found good practice and there are no difficulties arising from this unusual location. Heretofore it has been supposed that particles of dirt would be more efficiently swept out of the gas cylinder if the exhaust opening were directly under the lowest part of the cylinder, in which case the exhaust valves are not easily accessible.

8 The very full and complete paper of Mr. Freyn, with its voluminous report of working results, is an admirable and valuable addition to the literature of blast-furnace gas engines.

H. G. Stott. The problem of the cleaning of gas is similar to that of removing the moisture from steam. At the 59th Street Station of the Interborough Rapid Transit Company we first used an elaborate system of separators between the engine and the low-pressure turbine. The separator contained a series of baffles, each of which was supposed to take care of a certain amount of moisture. These baffles became loose and in order to keep the machine in operation we removed them. The result was an increase of 4 per cent in the efficiency of the separator. A new separator was designed so as to cause a sudden reduction in the velocity of the steam and we obtained a quality of 97 per cent. I believe the same principle applies to the elimination of dust from gas and that the real separation is effected by the sudden reduction of velocity.

2 I found from tests on the combined unit of reciprocating engines and steam motors that the thermal efficiency works out almost identical with Mr. Freyn's results, a little over 21%, the load ranging from 7000 to 15,000 kw. Any steam motor has the important advantage over the gas engine that it gives a wide range of operation with an efficiency curve that is almost flat. The burning of gas under boilers is a very much more efficient operation than the burning of coal and quite remarkable results have been obtained with gas-fired boilers. It would be interesting to note the results of so using the blast furnace gas and supplying the steam to the combined engine and turbine unit.

Edward A. Uehling. One of the most important parts of Mr. Freyn's paper deals with the cleaning of gas, a phase in blast furnace construction and operation that has been most sadly neglected in the past and even to-day is not fully appreciated except where the gas is to be utilized in the gas engine. But because of the dirt carried into the stoves by the gas their efficiency is greatly reduced, and to make up the deficiency in blast temperature a fourth and not infrequently a fifth stove has been added.

2 The cost of the additional stoves would have been more profitably expended in efficient gas-cleaning apparatus, because better results could be obtained from three stoves supplied with clean gas than from four or even five stoves mucked up by dirty gas. There are few stoves in existence in this country to-day whose heating surface, and consequently heating capacity, could not be quadrupled, if thoroughly cleaned gas was available. This also holds for the boilers connected with blast furnace plants; in most cases their output could

be very much increased and their efficiency doubled if served with clean gas.

3 It is worse than useless to line gas mains and a great deal of money could be saved, not only in refractory material, but also in the metal parts of the main and their supports. There is no excuse for the gas coming off from the furnace at a temperature so high that it will injure an unlined gas main. By applying water, preferably to the stock as it is charged into the furnace, the gas temperature can always be kept below 400 deg.

4. I have been one of the advocates of the blast furnace gas engine for a great many years. Before anything had been done along this line I calculated that there was 800 h.p. available above the needs of the plant for every ton of iron produced in 24 hours. Mr. Freyn has actually obtained about 600 h.p., showing that better results may yet be obtained.

S. K. Varnes[1]. American practice in blast furnace gas cleaning has simmered down to the three-phase process. The gas is first passed through dry preliminary cleaners, then through stationary wet scrubbers, and finally through rotary wet scrubbers. The gas is used for two purposes: it is burned in stoves and boilers or used directly in gas engines. Each of these uses requires gas of different characteristics. It has been found in German and American practice that gas containing from 0.15 to 0.20 grains per cu. ft. is sufficiently clean for boilers and stoves and it has been reported that dirty stoves can be cleaned by the use of such gas. For gas engines, however, one-tenth of this amount is all that is permissible.

2 In a number of cases it has been found that one centrifugal dust catcher removes 85 % of the dust which may be caught by the dry method and a second one is practically a waste of money.

3 Most of the secondary cleaning in the United States is done by a series of different types of washers, although at Steelton the secondary stage has been reduced to a single piece of apparatus. It is the secondary or stationary wet scrubber stage that I wish to mention especially.

4 I believe the first blast furnace gas engine to be operated in America was that at Steelton, a Westinghouse vertical engine, using a coke-filled scrubber to clean the gas. The enormous quantity of dirt promptly filled the scrubber, and the difficulties with engine

[1] Experimental Engineer, Pennsylvania Steel Co., Steelton, Pa.

operation were similar to those experienced at Lackawanna, due to lack of cleaning.

5 The most recent development of the scrubber may be said to be the Zschocke washer, built originally in Germany and, with modifications, much used in the United States. The primary washers described by Mr. Freyn are of this type. It is a type of scrubber in which an attempt is made to limit by the mechanical design the exact relation between the voids of the scrubber and the solid matter, consequently fixing the relation between the water contact surface and the area of the gas passages.

6 It would seem, however, to be a waste of money to build a tower of a certain size and then partially fill it with solid materials, thereby increasing the velocity of the gas through the tower and decreasing the time allowed for cleaning. If it were possible to present the same water contact surface and accomplish the same mixture of gas and water, and still maintain the full area of the tower, or very nearly so, it would be an advantage. This result is obtained by the sprinkling type of tower in which the grids or hurdles are eliminated and the water is caused to descend through the tower in drops. Of prime importance in this type of tower, however, is the uniform distribution of water and the breaking up of the water into sufficiently small particles. In case a particle of dust be brought into contact with a film of water, as in the Zschocke washer, if the dust particle is sufficiently small it may not be able to pierce the water film, due to the resistance of the surface tension of the water. Consequently, if the size of the drops of water be reduced to a point where they become much smaller than the size of the dust particles, the water particles will envelop the dust particles, weight them down and carry them downward by entraining acton, depending on the increased density of the dust particles with the film of water. The question of attaining this theoretical condition has been a difficult one.

7 The Mullen washer and the Moyer washer, which is a modification of the Mullen washer, are known as impinging types of washers. The gas comes into the top of the chamber, passes down through tubes, impinges upon a water surface, and then goes off in a reverse direction. The efficiency of such an apparatus as a gas cleaner, so far as dust is concerned, has been found to be very good, but the gas is not cooled in its passage through this scrubber, and frequently leaves at a temperature of about 300 deg. Gas at 300 deg. can contain about two hundred and sixty grains of water per cubic foot, and gas at the ordinary atmospheric temperature can contain only five

to seven grains per cubic foot, depending on the temperature. When this entrained moisture is carried into the stoves and boilers, it must be evaporated except for that which has been condensed on the way over. The loss is very material, and I know of one plant using a changed form of the Mullen washer that has abandoned its use in the original form because of the increase in the moisture content of the gas. If it were possible to cool the gas after the impinging action, it would be a very efficient type of scrubber.

8 The plant of the Penna. Steel Co. consists of a single type of apparatus for each of the three stages. For the first stage a centrifugal dust catcher is used; for the second, two similar sprinkling-type wet scrubbers; for the third, two similar rotary wet scrubbers. The plan of the cleaning plant is shown in Fig. 1. The gas travels from *A*, the downcomer from No. 3 furnace, into *B*, the centrifugal dry dust catcher, out through gas mains *C* and *D* to inlet pipes *E* and *G* of wet scrubbers Nos. 1 and 2 respectively. Leaving these scrubbing towers the gas may be taken off at one side through *H* to the rotary scrubbers or through *F* and *L* to the gas main *M* supplying stoves and boilers. An alternative course is provided from *E* through wet scrubber No. 1, out at *F*, thence to *G*, and through scrubber No. 2 to *H* or to *L*. The wet scrubbing plant may be by-passed to get gas to the stoves and boilers. The valves *V* are all water sealed. It is seen that the wet scrubbers may be operated in parallel (as originally intended) or in series if found necessary.

9 The scrubbing towers are each 25 ft. in diameter by 60 ft. high. The elevation is shown in Fig. 2. Gas enters through the brick-lined flue *A*, impinges upon the water seal surface *B*, passes up through the tower *C*, meeting there the rain descending from the distributor above and leaves at *D* or at *E*. The gas flues are brick lined as far as the towers, and the dry dust-catcher is brick lined except for some cast-iron wearing plates, in order that the gas may arrive at the tower as hot as possible. The hot gas immediately upon impinging upon the water seal gives up a portion of its heat in evaporating water which is quickly condensed by the rain from above. When this evaporated water is condensed from a gas to a liquid it necessarily passes through a state when the water particles are smaller than the dust particles carried by the gas and will attach themselves to the dust particles in condensing, thoroughly wetting them and weighing them down. In this condition they are readily washed out by the rain through which they are compelled to pass in ascending the tower. The distributor used in this tower for distributing water (Fig. 3) has been the

subject of a great deal of study and experimentation, and consists of a steel shaft A, extending through the top of the tower, with a bearing F on the outside, carrying at its lower end a wheel, the frame

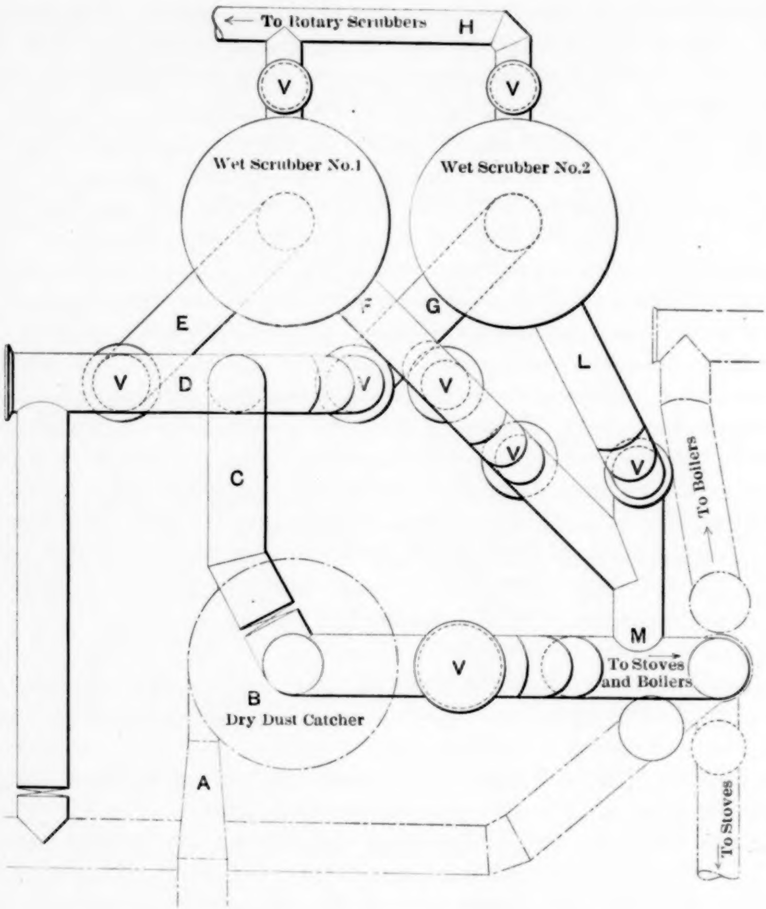


FIG. 1 PRELIMINARY GAS CLEANING PLANT

being of pipe work, and on the horizontal top surface C a screen of about one quarter inch mesh wire. This screen is rotated, water is brought in at the top through the nozzles D, bent at an angle of 90 deg., so that the water strikes the screen tangentially, at an angle to a radius, and opposite to the direction of rotation. This arrangement gives a practically uniform distribution.

10 Some of the advantages of this distributor are that there is no resistance to the passage of the gas from the bottom of the tower to the top, there being no obstruction whatever. It is possible by means of manholes to get at this single screen and clean it in case of obstruc-

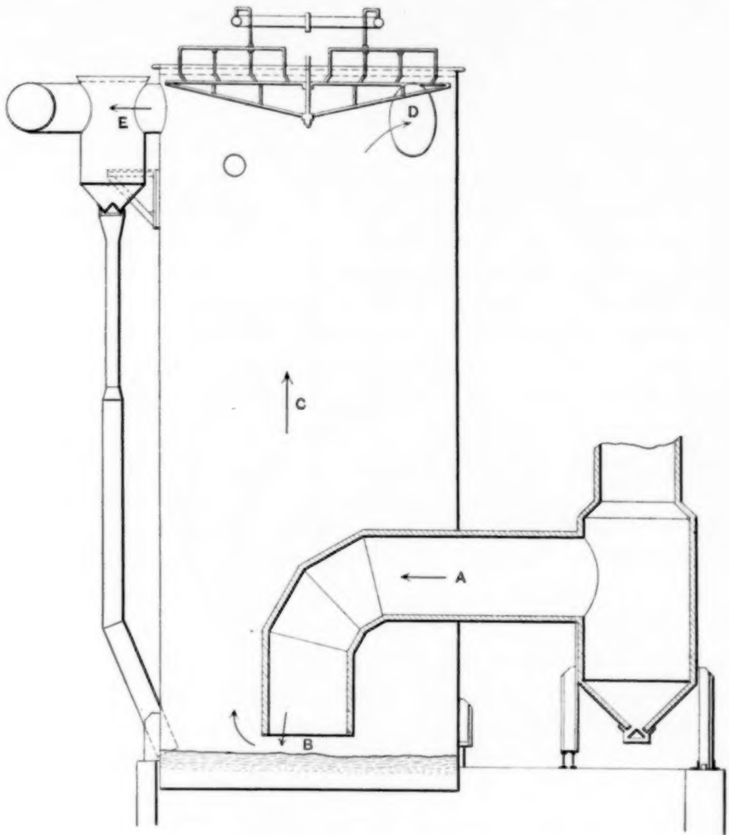


FIG. 2 SCRUBBING TOWERS

tion. The water nozzles are all connected to a manifold on top of the tower and are readily removable from the outside for cleaning in case of clogging. The water is carried to this manifold at about one pound pressure, just enough to lift it to the top of the tower. When the gas leaves the tower it is hoped to have it sufficiently clean to go to the stoves and boilers. It has been found in one scrubber tower that was built with a distributor, not of this type, but giving practical

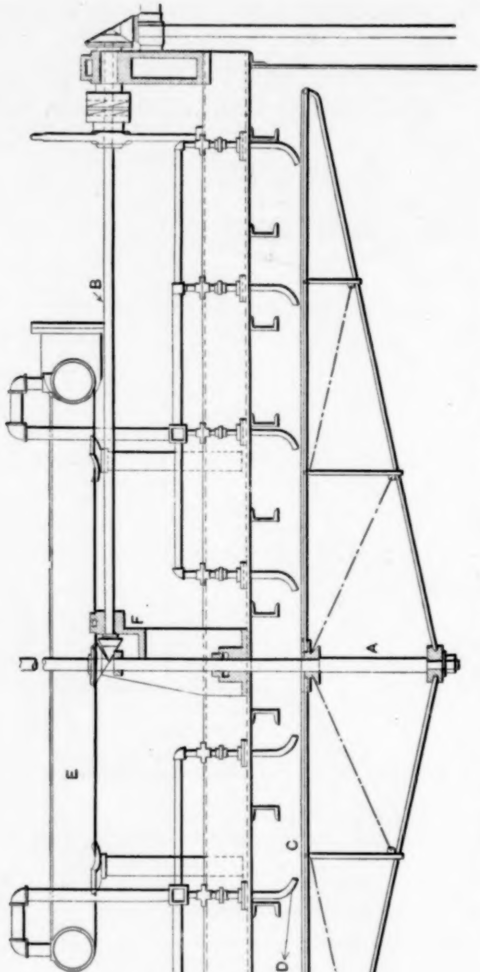


Fig. 3 Water Distributor in Scrubbing Tower

uniform distribution, that the gas was sufficiently clean for stoves and boilers in one operation, and we feel that we will be able to do the same thing. There is no resistance to the passage of the gas through the scrubber, and it should not be necessary to put in fans to force the gas to the stoves and boilers.

11 The gas from *H* goes to the secondary washers. For this operation I think there is no doubt that the Theisen washer will solve the problem very successfully.

H. G. H. Tarr.[1] During a recent trip to Germany I visited some of the larger iron works and was interested in observing the differences that exists in their method of preliminary gas cleaning. It is probable that this arises from the difference in ores and materials treated, as much as from the opinions of engineers as to the best methods. For final cleaning, however, the Theisen washer is quite extensively used. I was told in England, as well as in Germany, that gas was being delivered to the engines through these washers in a higher state of purity than existed in the air, and this seems to have been born out by experiences in this country. There is a very great probability that the time is not far distant when the air will be washed, as well as the gas.

2 This leads to the thought that this method may be adopted for cleaning the air entering churches, hospitals, theaters and wherever there are large assemblies of people.

Edward Rathbun. Probably the most serious thing we have to consider as engine builders regarding producer gas engines is the question of gas cleaning, or to be exact, the cylinder wear, and in conjunction with the valuable information contained in Mr. Freyn's paper, I would very much like to see some data regarding the relative wear of the engine cylinders as the various cleaning processes were developed.

Jesse M. Smith. When I was building blast furnaces in Central Ohio, prior to 1880, we were smelting native ore with raw bituminous coal containing a tremendous amount of dust, which not only stopped up the flues but also the space below the boilers and in the ovens. To remove this difficulty we discharged the dust vertically downward from the blast furnaces into a cylindrical chamber 12 ft. in diameter

[1] R. D. Wood and Co. Camden, N. J.

and water-sealed at the bottom. This chamber was several times larger than the down-comer. The gas ladened with dust came down against the water and the major part of the dust was caught, to be removed through the water seal. This apparatus worked admirably and after its installation we were not troubled with dust in flues, under the boilers or in the stoves.

2 I have found in this connection, as well as in the cyclone dust catchers used in flour mills, where the centrifugal motion is used, that final separation of fine dust from air or gas must take place, as Mr. Stott has said, by sudden reduction of the velocity so that the gas has an opportunity to deposit its heavy portions on a surface that will catch and hold them.

Charles Whiting Baker. To obtain clean gas for engines, the use of a water spray results in great reduction of temperature. It is also possible that in modern practice where very fine ores are used, it may be necessary to employ water for cleaning the gas to be used under stoves and furnaces. The 300 to 400 deg. of heat lost in the cleaning process would be worth while saving if we could discover some means of dry cleaning the gas. It is entirely possible that by using the dynamic process or the type of cleaning used in flour mills the gas might be dry cleaned and delivered to the stoves and furnaces at its original temperature.

E. P. Coleman. As stated in Appendix No. 5, contributed by Mr. Bacon, certain liberties were taken in the design of the 60-in. Venturi meter, in that the junction between elements of the upstream cone and the cylindrical throat is angular, not being formed by means of an easy curve as is usual. By referring to Fig. 23*b*, it will be further observed that the distance from this angular junction to the $\frac{3}{16}$-in. holes communicating with the angular pressure-chamber is relatively small. The coefficient of 0.91 for this meter as determined by means of the gas-holder, is in all probability correct, but it is believed that, if the junction had been rounded, or the $\frac{3}{16}$-in. holes situated farther down stream from the angular junction, or both, that the coefficient would have been greater. In addition to the probable eddy loss noted by Mr. Bacon, it seems probable that a contraction of the stream also occurs at a point in the stream opposite these holes. Each of these conditions, if existing, will lower the coefficient. By rounding the junction the eddy loss is reduced; and by locating the pressure holes at a section of the throat which is filled

by the stream, the pressure difference should more closely approximate the ideal.

2 Considering the extraordinary facilities provided by the 100,000-cu. ft. gas-holder for accurately determining such coefficients, it seems unfortunate that commercial reasons were allowed to affect the design. The writer believes that a Venturi meter of 6-in. diameter or more, and of the best design and construction, will show a coefficient greater than 99% with usual gas velocities.

A. Bement. While the successful outcome of the plant described by Mr. Freyn is cause for congratulation, it is probably correct to say that if the application of the gas engine in connection with blast furnaces had been delayed much longer it might have found very strong competition in the gas-fired boiler supplying steam to turbines direct-connected to electric generators and to blast furnace blowing engines.

2 Relative to safety devices, the writer believes their use in all possible cases to be desirable, and is inclined to the belief that the feeling of opposition to them is based upon the assumption that they will be expected to take the place of manual supervision. Where safety devices have been successfully employed with delicate electrical apparatus marked success has been secured. It was necessary, however, that the apparatus be watched and kept in order. Its use is not for the purpose of taking the place of the watchfulness of the men, but as supplementing it.

3 Contrary to expectation when the use of furnace gas in engines was proposed in Europe, it has been found that the removal of dust from the gas is a matter of the greatest importance This is especially true in this country because of the finer ore and harder driving of furnaces. In this connection dry air blast promises to effect a marked reduction in the amount of dust carried by the gas, as its use appears to result in very much more even working of furnaces and a very marked reduction in the number of slips.

W. E. Snyder. This paper is without doubt the best description and operating record of a blast furnace power plant that has ever been published, and great credit is certainly due the broad-minded officials of the company operating this plant for their action in making the data available. Great credit is also due to Mr. Freyn for the very complete records which he kept and for their very clear and thorough presentation. A discussion of this paper is possible only by

considering the subject of the paper as a topic upon which others may add their experiences. I will discuss the paper in this way, giving some notes relative to European operating experiences and comparisons with American conditions.

2 During the early part of 1908 I had the opportunity of investigating gas engine practice in almost all of the countries of Europe in which gas engines are used. During this investigation I visited 29 different plants on the Continent, and saw in round numbers 365,000 horse power in operation. I also visited eight different works where large gas engines are built. At all of these plants I had opportunities for discussing their experiences with different engineers and operating men in charge. Although this was about two years ago, the development of gas engines and gas cleaning had at that time proceeded far enough to evolve certain standards of apparatus and methods of operation which have not changed materially since then.

3 The country which has made the most rapid strides in the development and use of large gas engines driven by blast furnace and coke oven gas is Germany. The first small gas engine to use blast furnace gas in Germany was put in operation in October 1895. In the early part of 1906 Dr. Reinhardt, of the Schüchterman & Kramer Works, estimated that there were then under construction or erection or in operation in German steel works 349 large gas engines, aggregating about 385,000 horse power, and in German collieries 35 gas engines, aggregating 30,300 horse power, a total of nearly 400 large gas engines. By far the larger proportion of these were installed during the period from 1902 to 1906. Other countries made contemporaneous progress, though not on such a large scale.

4 The effect of this rapid development in an entirely new field was that the early experience of many of the gas engine stations was one of continued and varied troubles. These troubles, while exasperating to the engineers in charge of operations and discouraging to the financial managers, constituted the experiences from which were evolved the very satisfactory European installations of the present day and the large installations in this country. European experience during this period of development, while very interesting, is of no importance compared with operating results from the more recent large gas engine installations, such as are given in Mr. Freyn's paper.

5 A feature of the use of large gas engines in Europe is the great confidence reposed in them by both builders and users. Gas engines were put in to work under the greatest variety of conditions, not alone for blowing blast furnaces and for electric driving, but for the

direct driving of mills, of which I saw several installations, including merchant and small bar mills, rod mills and sheet mills. One steel plant was equipped with a large gas blowing engine for the converters. At two works some of the gas engines were so constructed that they served for driving either blowing cylinders or electric generators as might be required. At other works a mixture of coke oven and blast furnace gas was used, or even producer gas and blast furnace gas. In fact, there seemed to be no hesitation whatever in depending on the gas engine to operate under as widely varied conditions as the steam engine, and this confidence in what could be done with the gas engine was usually justified by the results. Sometimes, of course, there was a great deal of trouble and expense involved, but the work went on without change in general plan.

6 The type of engine which seems to be the general favorite in Europe is the same type that has been adopted for almost all of the important installations in this country. This is the four-stroke cycle, either single or double tandem. There have been long and learned discussions among the technical men of Germany on the relative merits of the two-stroke cycle and the four-stroke cycle engines, but the type which has predominated was not determined by these academic discussions. It was determined by the engineers who were responsible for operation and results.

7 Emphasis is everywhere laid on the necessity of good technical supervision over gas-engine power stations. As the prime requisite for good operating results, a good gas engine is specified; for the second requirement, efficient technical supervision is provided, coupled with records of running conditions somewhat similar to those presented in Mr. Freyn's paper, though not so complete.

8 The primary necessity for a good engine to begin with seems so self-evident, but it indicates the responsibility that is everywhere placed upon the engine builder. The greatest troubles which develop are due to fire-cracking of the cylinders and pistons. The design of those parts is now much better understood than at first, with the consequent prevention of most of these difficulties. A very common size of cylinder in the newer installations is 1100 m.m. (43.3 in.) diameter and 1300 m.m. (51.3 in.) stroke. Each cylinder of this size at 95 revolutions develops about 1000 horse power, which requires a m.e.p. of 56 lb. Cylinders of this size and smaller were complete of one casting without a bushing. Since the time of my visit, however, cylinders have been designed and constructed to develop 1300 horse power each, approximately 52 in. in diameter by 56-in. stroke. There

have also been developed cylinders made of two or more castings fastened together by strong and tight joints. This is to avoid the difficulties due to shrinkage stresses and to the stresses in the casting caused by the difference in temperature between the inner and outer walls. Hard cast-iron bushings are also used, and some engineers are considering steel cylinders, if indeed they have not already been constructed.

9 These most recent developments in the construction of cylinders are very radical changes from what was the practice among leading builders but two years ago. Whether these changes are due in part to American experience or not it is not possible to say, but evidently the design of multicasting cylinders with bushings is due both in this country and in Europe to a common cause, the effort to increase the reliability of the cylinder, which result is certainly accomplished.

10 The operation of gas-engine driven generators in parallel at 25 cycles was common, as was also their operation with steam-engine driven units in parallel. The operation in parallel of two or more plants, gas or steam driven, but located at different places, was also practiced. Many of the newer units installed do not have flywheels, the entire flywheel effect being produced by the rotating part of the generator. The yoke frame is usually used, i.e., the main frame is designed with a bearing on each side of the crank. The various details, such as valve gears, regulating mechanism, igniters, etc., were in various stages of improvement, the object everywhere being to simplify and at the same time to retain or improve the efficiency and reliability of operation.

11 The newer installations in Germany are splendid examples of engineering accomplishment. This is true not alone of the gas engines but also of the electrical apparatus, buildings and auxiliary equipment as well. Every detail seems to have been given attention, and where previous experience, or engineering foresight could serve as a guide, provision has been made for convenient and economical operation. One of the stipulations in contracts for gas engines now being installed is that after all adjustments have been made and the engine put into regular service it must run for four weeks continuously without stop or slow-down, and there is no difficulty whatever in fulfilling this condition.

12 With regard to the cleaning of blast furnace gas, there was almost every conceivable combination of dry dust catchers, vertical washers, and rotating washer devices, such as fans, Theisen machines, etc. Many works do not have Theisen machines in use for fine clean-

ing the gas, but use two or three fans in series. However, I did not hear any unfavorable criticism of the Theisen apparatus from anyone. The opinion was general that it was the most efficient method of fine cleaning the gas that had then been devised. Considering the gas cleaning proposition as a whole, from the furnace to the engine, I did not see any installation superior to the best installations in this country, and I doubt if their equal exists in any of the European works. There is a reason for this in that the importance of cleaning gas thoroughly was fully realized in this country when gas engines were first considered, while in Europe it was at first thought that cleaning was not of much importance. The extended European experience with different systems and apparatus for cleaning gas for gas engines was available for the American steel works engineer when he first took this matter up, while there was no such experience available for the European engineer and all of the apparatus required had to be developed. There is a greater difference between the best gas cleaning plants in this country and in Europe than there is between the gas-engine power stations, or more particularly, the gas engines themselves. There is a strong probability that the reason for this is that here the steel works engineer, whether consciously or unconsciously, made more use of gas cleaning experience in Europe than was made of European gas-engine experience by the American designer. It is a fact that there has been practically no trouble here in the thorough cleaning of gas for engines in the principal installations, while there has been a great deal of trouble with the gas engines themselves in these same installations. Most of these difficulties have now been overcome, but many of them could have been avoided if the American designer had profited by the fund of European experience which was available when he first began his work.

13 The following may be given as interesting items of comparative data with reference to gas cleaning: Dr. K. Reinhardt found that the water consumption of Theisen machines varied in different plants from 22 to 60 gallons per 1000 cu. ft. of gas cleaned. The plant described by Mr. Freyn used an average of 19.4 gal. per 1000 cu. ft. Dr. Reinhardt also determined the horse power per 1000 cu. ft. of gas cleaned by Theisen machine to vary from 0.17 to 0.37. Calculation from the data given by Mr. Freyn shows that the Theisen alone required 0.20 h.p. per 1000 cu. ft. of gas. German practice had come to regard 0.02 grams of dust per cubic meter, equivalent to 0.009 grains per cu. ft., as a standard for cleanliness of the gas. This was a compromise between what was thought possible for a gas cleaning

plant and what was desirable for gas engines. The average dust contained in fine gas for the year as given by Mr. Freyn's paper is 0.0058 grains per cu. ft. which is about 65 per cent of the approximate maximum fixed by German practice as standard.

14 The velocity of the gas allowed in the different mains and pipes as given by an experienced engineer was as follows: In large gas mains from 15 to 20 ft. per sec.; in smaller pipes connecting the different parts of the gas cleaning apparatus, 33 ft. per sec.; in branch pipes going to engines, 66 ft. per sec.; in valves and gas passages of the engines 130 ft. per sec.

15 In some of the plants no charge was made to the power station for gas used. At many of the largest and most modern installations, however, a charge was made for the gas. This charge was determined by measuring approximately the quantity of gas used per month and calculating from its average composition the heating value of the gas per cubic meter. This was then evaluated by comparing with the heating value of standard coal used at the plant. In a few instances gas calorimeters were in use, but all instruments for measuring or testing gas were in process of rapid evolution and no method had general acceptance, either in the engineering or accounting problems involved in valuing the gas and accounting for it.

16 Venturi meters were not used in any plant for measuring gas. The usual method of determining the quantity of gas was to use an instrument based on the Pitot tube principle, the tube being located at a point in the cross section of a straight run of pipe which has been determined by test to be approximately that of average gas velocity. The instrument was nearly always of the continuous recording type, with charts graduated to record gas velocity.

17 For lubricating the gas engine cylinders, the largest and heaviest types of lubrication that I have ever seen were in use. These lubricators were of very massive construction, and were frequently placed on the floor beside the gas engine, looking not unlike small vertical engines. They were connected to a number of oil pipes, which supplied lubricant to the cylinders, exhaust valves and rod packing. The cylinders were usually fitted with from four to six oil pipe connections, these being placed where, in the judgment of the designer, they would do the most good. It was not the practice to attempt to discharge oil in the cylinder at any particular point in the stroke. The method of driving the lubricator prevented this.

18 There was great variation in the kind of oil used, but the concensus of opinion agreed that the cylinder oil should be of light body,

containing a minimum of heavy carbonaceous matter. The only test I could find being applied to oil for gas engines was that the smaller the residue when the oil was vaporized the more suitable it is for gas engines, provided that it has the general characteristics of good lubricating oil. At some plants they were using oil of the same kind in the cylinders as was used in the bearings and pins of the engine.

19 At many of the large installations great care is taken to provide for the safety of the men in charge of the gas engines and gas cleaning. Various kinds of safety apparatus are placed where they will be quickly available in case of accident, and the men are trained in the use of this apparatus. There are also rules in force which are intended to promote safety conditions. One of these provided that no less than two men shall work together, the presumption being that in this case there will always be one to raise the alarm in case a man is overcome by gas. Another rule provided for the proper ventilation of cellars and the prevention of gas pockets about the foundation or building. As a result of these precautions accidents due to the effects of gas are said to be very infrequent.

20 During the past two or three years very rapid progress has been made in this country in the improvement of details, both in the design and construction of engines and in their operation. Some American engineers have done splendid work in designing large gas engines to meet American conditions. One of the most important improvements is the cylinder made of two or three different castings, fitted with a hard cast-iron bushing. The use of steel castings for cylinders is also an important development. It is not intended to imply that these features of cylinder construction are distinctively American practice, but American conditions and designers are no doubt largely responsible, since this form of construction developed very soon after the manufacture of large gas engines began in this country.

21 Another improvement in detail that is distinctively American is in the method of lubricating the cylinders. It is now very general practice here to have two oil pipes for each end of cylinder, each pair being located at the top of the cylinder, one a short distance on each side of the center line. The oil pump is connected in such a way that the oil is discharged at the beginning of each suction stroke where the piston covers the oil holes. The lubricators used for delivering the oil to the cylinders are much smaller and less cumbersome than those in use in foreign plants and seem to be just as satisfactory. A system of forced-feed lubrication for all bearings, pins, etc. has been

developed and is now in successful operation. This is of special importance in that it contributes towards higher piston speed, thereby reducing the first cost per unit of capacity and the floor space required.

22 The governing mechanism has also been improved to such a degree that all principal builders are ready to guarantee successful parallel operation of 60-cycle a. c. generators. This is also an improvement, but it came too late to influence the characteristics of the principal installations now in operation. At these plants the 25-cycle system was selected of necessity and must now be adhered to because it is too thoroughly established to permit of change.

23 Still another important improvement in detail which is distinctively American is the kind of cylinder used in large gas blowing engines. The blowing cylinders I saw on most of the gas engines of Europe, I consider the poorest part of the whole installation. A large proportion of these cylinders have the old type mushroom poppet valves for both inlet and discharge. While these may have been fairly well suited to the low blast pressures carried at most of the European plants, they are wholly unsuited to American conditions and to use them on gas engines here would be going back to the practice of 15 or 20 years ago. In order to get the most efficient results from a gas blowing engine, mechanically operated valves are necessary. This fact has been fully appreciated by American designers and some splendid examples of cylinders fitted with this type of valve have been produced. The equal of these American blowing cylinders with mechanically controlled valves is not made anywhere in the world and their use facilitates higher rotative speeds, which in turn reduces unit first cost and floor space. Speed control for blowing engines is a feature in which the best American engines equal the best used in Europe at present.

24 Gas cleaning, the construction of gas engines, and their operation are all now well understood in this country. The engineering problems involved are appreciated, even though they are not all solved. The commercial features involved are not of the most importance because a gas engine installation will in this country, for years to come, be a very expensive installation per unit of capacity. The price of fuel at all blast furnace plants in this country is low compared with what it is in Europe. The manager, in considering gas engines, must face the American aspect of high plant cost and low fuel cost. In this connection any improvement, such as forced-feed lubrication mechanically-controlled air valves, etc. which facilitates higher piston speeds, is an improvement which makes the large gas engine

more generally available for consideration in American plants. What is required is to increase the earning capacity of any given unit or installation. High load factor at nearly continuous operating conditions is one of the principal requirements for gas engine plants. It will therefore be seen that while a collection of data as given in Mr. Freyn's paper is of great interest from an engineering standpoint, it is also of particular importance in its bearing on the commercial use of gas engines, i.e., it is a record of the efficiency or output of each principal part of the power plant, so that it is always known whether or not the installation is maintaining the best operating efficiency consistent with the operation of the works which it serves.

THE AUTHOR. As Mr. Maccoun states, all large gas engines built in this country are of the side crank type, as this design was insisted upon by the steel works' engineers, and it cannot be denied that the side crank design proved to be very satisfactory and has many advantages over the center crank construction, but it should not be overlooked that it makes American gas engines considerably heavier and more expensive than European engines, which are without exception built with center cranks.

2 Regarding the question of governing gas engines, the governing by constant mixture is decidedly favored by American engine builders, and it appears that this system gives more satisfactory results in our practice than the so-called constant-compression-stratification method of governing.

3 I cannot agree with Mr. Maccoun that it is of such great importance to use some particular brand of cylinder oil for lubricating gas-engine cylinders. At the plant under discussion very excellent results are being obtained by the use of standard gas engine oil, which has about the following characteristics:

Viscosity Tagliabue	Flash point deg. fahr.	Fire point deg. fahr.	Spec. Gravity
79.1	395	456	0.912

This oil is considerably less expensive than the special heavy oils suggested by Mr. Maccoun, whereas the quantity consumed is not very much greater, so that the net result is a material economy in the cost of lubrication. Frequent cylinder examinations have proved that the use of standard gas engine oil does not entail carbon deposits, since the oil is burned up completely, not leaving any residue in the counterbore nor under the piston rings. This, in my experience, cannot be said of the high-priced oils which, in order to obtain the

high flash and fire points, must necessarily contain heavy hydro-carbons.

4 In regard to the amount of power obtainable from blast furnace gas, I think that the figure of 25 h.p. per ton of pig iron produced in 24 hours is pretty generally admitted to be a reliable basis for general calculations of the available power. It is true that this figure does not apply in every particular instance, and especially not in cases of plants having less than two or three blast furnaces. There are plants in existence, however, where practically no coal is burned under the boilers, and where all power requirements for the mills are being supplied by the excess gas from the blast furnaces. The Gary works of the Illinois Steel Company exemplify this statement.

5 Mr. Maccoun is perfectly correct in maintaining that the gas engine is not the universal panacea for the needs of a blast furnace plant. In isolated plants, for instance, where a large proportion of the gas produced by the furnaces must go to waste simply because there is no field for its utilization, and where the gas is therefore of no value, the installation of costly gas engines may be uneconomical and undesirable. In other plants there may be old steam engines in operation which are running so satisfactorily, though not economically, that they may render good service for years to come. In such cases it would be a waste of money to discard these engines and to replace them by gas engines, since the low-pressure steam turbine is available to improve materially the thermal efficiency of such plants.

6 In connection with the question which has aroused most of the discussion, namely the preliminary cleaning of blast furnace gas, it seems to be the unanimous opinion, brought out by Messrs. Morgan and Uehling, that it is obsolete practice to use raw blast furnace gas for any purposes about a blast furnace plant. It is generally recognized today that the gas for hot blast stoves and boilers should be cleaned to prevent the deleterious effect of the flue dust on the checker brickwork in the hot blast stoves and on the boiler flues. Opinions, however, are divided as to the degree to which blast furnace gas for these purposes should be cleaned, as well as to how this cleaning should be performed. According to the information obtainable on the subject at present, it does not seem possible to clean blast furnace gas by a dry process alone to such a degree of cleanliness as is claimed to be desirable in some of the discussions.

7 While it would seem consistent to assume that the benefit derived should increase proportionally with the degree of cleanliness of the gas, this is not so, since the ultimate economy is not only depen-

dent upon the increased life of the checker work in the stoves, the high heats obtainable and the reduced labor of cleaning stoves and boiler flues, but also to a very great extent upon the cost of installation, operation and maintenance of a gas-washing plant.

8 The discussion of this phase of the problem of gas cleaning bears out the general conviction that if blast furnace gas could be sufficiently cleaned by a dry process only, such a cleaning plant could be installed, operated and maintained at a much lower cost than if wet scrubbers, pumps, fans, etc., were necessary to accomplish the purpose in view. My opinion is that dry cleaning of the blast furnace gas can be most effectively accomplished in an apparatus fulfilling the following three conditions:—

a Reduction of temperature of the gas
b Sudden change of direction
c Sudden reduction of velocity

As explained in the body of the paper, a reduction of temperature of the gas can be accomplished without expense by the use of unlined gas mains. Too much importance should not be attached to the advantage of preserving the sensible heat of the gas, and calculations at the plant under discussion have shown that the loss due to reduction to atmospheric temperature does not exceed 8%. On the other hand any reduction in temperature of the gas is coincident with a corresponding reduction of moisture, a very important factor in the economical burning of the gas in stoves and under boilers.

9 The design of any effective dry cleaner should make it impossible for the dust to be stirred up after it is once deposited and this implies provision for carrying off the separated flue dust in such a manner that it is protected as much as possible from the effect of slips and the tendency of the gas current to entrain the dust particles. Any dry cleaners based on the action of centrifugal force are necessarily much more effective than the old type dust catchers, wherein the separation of the dust occurred merely by the reduction of velocity in voluminous chambers. Granting the above requirements for an effective dry cleaner, the horizontal dust separator described by Mr. Morgan must prove to be a very efficient dry cleaner.

10 At the plant under discussion a great deal of experimenting on a large scale was done in connection with this problem. As explained in the body of the paper, very voluminous dry dust catchers of the tangential type were installed at all furnaces, but it was found that the efficiency was comparatively low.

11 A new development in the dry cleaning of gas is now being

perfected at this plant, and it promises to solve the problem in a very simple, inexpensive and effective manner. This is the Brassert-Witting dry dust cleaner, letters patents for which are now pending. This dry cleaner combines in one apparatus the above named principles of successful dry cleaning, since it is unlined, makes use of centrifugal force, positive friction, reversal of direction and sudden expansion of the gas while protecting channels take the dust out of the path of the gases. These dust catchers are inexpensive and the operating cost is practically nothing, as they discharge the dust directly into railroad cars. The advantage of this system, aside from the low cost, is the fact that all the dust is recovered in a dry condition, doing away with the nuisance of sediment in sewers, river, etc. It has been shown in actual practice that one of these ten foot Brassert-Witting dry cleaners will take out about twice as much dust as a large forty foot dry dust catcher of the system preceding it, and with three of these cleaners in series, it is possible to obtain a cleanliness of less than one-half grain of dust per cubic foot.

12 With reference to Mr. S. K. Varnes' contribution on the question of wet gas cleaning, it is unquestionably true that this object can be satisfactorily accomplished in wet scrubbers other than the one described in the paper. Whether, however, such wet cleaners are more effective and cheaper in operation is yet to be proved. The four wet scrubbers in the plant under discussion, now operating in parallel, show an efficiency of over 90% for the last three months. The reduction of gas pressure to which Mr. Varnes refers is of no consequence since it does not exceed one inch of water column.

13 I cannot imagine a better distribution of water than that obtained in a tower filled with hurdles, since the water falling from hurdle to hurdle on its way from the top to the bottom of the wet scrubber is broken up again and again into a very fine mist so that practically every particle of gas must come into thorough contact with the water. I do not believe that the dust particles have to pierce a water film in order to be removed from the gas, but that the action which takes place in any type of scrubber consists in the wetting and weighing down of the dust particles by microscopical water drops in suspension.

14 The influence which impurities in the gas have on the cylinder wear can practically be disregarded if the engine gas is thoroughly cleaned in a modern cleaning plant. Conditions have changed materially in this respect in the last eight or ten years. Before adequate gas cleaning plants were in use the amount of impurities carried into the

engines was so great that the dust and the lubricating oil formed a grinding material which caused the cylinders to wear out in a distressingly short time. Cylinder wear in modern blast furnace gas engines is not primarily due to the dust, but to the material of the cylinders, piston ring design, lubrication, etc.

15 Mr. Stott mentioned that he has obtained with a combination of reciprocating steam engines and low-pressure steam turbines, a thermal efficiency of over 21%. It is evident that Mr. Stott is referring his thermal efficiency to the total amount of heat contained in the steam at the engine throttle and that he does not take into account the losses occurring by steam transmission between boiler house and engines, nor the efficiency of the boilers themselves and the losses in the boiler house. Inasmuch as in a blast furnace plant the blast furnace gas is the available fuel, which in one case is used directly by combustion in the gas engine cylinders and in the other case indirectly under boilers for raising steam, a fair comparison of the efficiencies of these prime movers can be made only on the basis of the amount of heat units contained in the gas delivered at the gas cleaning plant in the former and at the steam boilers in the latter case. Assuming that the combined losses in boilers and by steam transmission to the engines amounts to 35%, so that the combined efficiency of boilers and steam pipe is 65%, the thermal efficiency of Mr. Stott's installation would not exceed 13.7% compared with about 21% realized with our gas engines.

16 The latter figure, moreover, is not a value obtained by one or a series of individual tests, but is the average of the results obtained in actual commercial operation of the plant during the period of one year; nor is this figure in any way exceptional, as there are gas engine plants in existence abroad where average thermal efficiencies of 25% and more are being realized. There is no reason why with mechanically perfect engines of modern design these figures should not be duplicated and even exceeded in this country.

17 Mr. Coleman's discussion was submitted to Mr. C. J. Bacon, who states that the matter of which Mr. Coleman speaks namely, accounting for losses in the Venturi meter, was not included in the paper as there was no definite information available on the relative losses due to eddy currents, location or pressure holes, imperfect workmanship, etc. Mr. Bacon fully agrees with all that Mr. Coleman says.

18 It is with particular pleasure that I refer to Mr. W. E. Synder's remarkable contribution as one of the most valuable accounts

of European gas-engine practice which has yet appeared in print and it will undoubtedly prove of great interest and value to the profession. Having had experience in both European and American gas-engine practice and having actively witnessed the early development of the blast furnace gas engine here and abroad I feel competent to endorse the views expressed by Mr. Snyder in every particular.

19 In preparing my paper I purposely refrained from broaching the subject of gas engine design and construction; nor did I yield to the temptation of relating my personal experience with gas engine operation here and abroad, well knowing that my reference to these subjects would have brought out a veritable avalanche of discussions on the part of both gas-engine builders and users. In line with this reasoning I do not care to take up point by point Mr. Synder's remarks on the construction of certain gas engine parts, but I wish to elaborate a little on one statement which is in line with the subject matter of my paper.

20 It is an established fact that all gas cleaning plants installed in this country within the last five years have been very successful and practically free from trouble. This is largely, if not exclusively, due to the insight of American steel works managers, who recognized that in view of what had been done in Europe along this line any attempts to solve the problem inadequately by carrying on lengthy and costly experiments would have meant wasting money and retracing again the steps which their European colleagues had taken before. Instead they willingly took advantage of the experience of others and adopted European methods and apparatus, perfecting them to meet their own conditions. It is equally true that many of the difficulties encountered in the operation of our gas engines in this country would have been avoided if this principle of profiting by the experience of others had been more closely adhered to in designing and building American gas engines.

21 It is very gratifying to note the close coincidence of the results obtained in American and European operating practice, especially in regard to the purification of blast furnace gas and the lubrication of gas cylinders.

CRITICAL SPEED CALCULATION

By S. H. Weaver, Published in The Journal for June 1910

ABSTRACT OF PAPER

The motion of a rotating shaft is treated mathematically as vibrations along two axes at right angles to each other. Properties of the equations of vibration are discussed and curves given showing the amplitude of vibrations at different speeds for various shaft loadings, spans and bearing supports. For the points of maximum vibration, the general formulae are reduced to special forms and given in a reference table for convenient use.

DISCUSSION

Henry Hess. In all of the valuable formulae developed by Mr. Weaver the center of support at the journal is assumed as a definite single point. As a matter of fact, machine journals are not definite single points but vary in length from one to five shaft diameters. It is usually assumed that the center of pressure in a journal with a load to one side of the journal is at a point about one-third the length of the journal, or that such a point is at the center of the journal when equal loads are overhung at both sides. As a matter of fact, however, the actual position of the average load is entirely undetermined. It may be at the assumed point, at one end or the other, or at any point between.

2 If a journal is scraped so as to be absolutely parallel and to fit the shaft throughout its entire length, a measurement of the journal and shaft after being used for some time will show that the journal has become bell-mouthed. A similar measurement later will show that the bell-mouth has changed to the other end of the journal. Any measurement taken between these times will show that the journal is bell-mouthed at both ends. A frequent repetition of such measurements will show that the shape of the journal is continually changing. It follows from this that the point of load concentration is also continuously shifting from end to end and back again.

3 It must be manifest that any formula based on the assumption

of a fixed point of support must fail of giving satisfactory results. No doubt this fact explains much of the trouble experienced in designing elements which are to rotate at high speeds.

4 The solution is, theoretically, a very simple one. It is to provide a journal in which the point of support is definitely fixed to agree with the lengths of the load lever arms assumed in the formula. From a practical standpoint this demands that the journal be of zero length, a requirement which is insurmountable so long as plain journals are used. The difficulty ceases, however, as soon as a ball bearing of that type in which a single row of balls carries the load and in which the contact between the balls and races lies in a plane at right angles to the axis of the shaft is resorted to. This concentrates the load at the theoretical point, or plane, of the formula. When it is desired, the greater stiffness which is given the shaft by the support of a long journal can be realized by using two ball bearings of the type referred to, separated by such distance as is desirable. Here again the points or planes at which the load is supported in the journal are definitely fixed and cannot shift.

S. A. Moss. It is not necessary, as stated by Mr. Hess, to know the exact center of support in the bearings. Vibration at a critical speed is not at a single speed, but through a considerable range on either side of the computed critical speed, the extent of the range varying as the speed is increasing or decreasing or as the acceleration is fast or slow. Hence exactness is useless. I have run some machines with ball bearings, and have not noticed any difference in the range of critical speed. Any change in the point of support simply means that the critical speed comes at a very slightly higher point, a few per cent in most instances.

2 At the critical speed there is the synchronous transverse vibration of the shaft, as has been pointed out, and the simple deflection of the center of gravity does not really occur. The shaft is rotating at the same time it is vibrating and if there is any unbalancing, the center of gravity shifts from the inside to the outside during the course of the transverse vibration. In the vicinity of the critical speed, the shaft is going back and forth between the two positions, and finally, beyond the critical speed, the transverse vibration dies out with the center of gravity on the inside.

M. Nusim. Mr. Weaver makes a passing reference to a paper by Professor Morley where a highly important formula for the calcula-

tions is critical speeds is published. Using engineering units this formula is as follows:

$$N = 187.7\sqrt{\frac{\Sigma\, Wy}{\Sigma\, Wy^2}}$$

where N is the lowest critical speed in revolutions per minute, W is any of the weights on the shaft measured in pounds, and y is the corresponding static deflection in inches if the shaft were horizontal. ΣWy represents the sum of the products of each load into the corresponding static deflection. ΣWy^2 represents the sum of the products of each load into the square of the corresponding static deflection. The formula is applicable to a shaft of constant or variable diameter with any number of loads and with any number of bearings, and it includes all of the simple cases given by Mr. Weaver. For such cases there is little preference between the two forms. The Morley formula also covers the more complicated cases (with three loads, etc.), which the simple formulae do not treat, but gives the first or lowest critical speed only. It has been given by Dr. C. Chree in a form suitable for comparing with and criticizing Dunkerley's empirical formula for critical speeds,[1] and was published later, in the condensed form given above, by Prof. A. Morley.[2] The formula mentioned is based on a theorem due to Lord Rayleigh, which states that the period of vibration of a shaft is not affected appreciably if we depart materially from the true shape the elastic curve takes during vibration. This theorem is related to the calculation of critical speeds in so far as a knowledge of the elastic curve of the shaft at this speed is sufficient for the calculation of it. The formula is derived by taking the shape of the elastic curve during whirling to be the same as that due to the elastic loads acting on the shaft when it is horizontal and at rest.

2 It should be noted that in the case of uniformly distributed loads the summations under the radical in this formula become integrations. If these integrations are carried out for the four cases of uniformly distributed loads in Mr. Weaver's table it is found that the error involved is a small fraction of one per cent.

3 In the case of a shaft of constant diameter with two loads symmetrically situated (two or more bearings), the formula follows directly without seeking support from Rayleigh's theorem. This is

[1] Philosophical Magazine Vol. 7, p.542.

[2] Engineering (London), August 1909.

also true for any number of loads so situated that the deflection under each load is the same.

4 It is also easy to see that the formula covers the case of a shaft of constant or variable diameter with a single load. In applying the formula to shafts having more than one span (three bearings or two bearings with overhanging load), it should be seen that the elastic curve has zero deflection at the bearings only, for the reason that at the first critical speed, nodes can only exist at the bearings. On account of this it will in general be necessary to consider the loads on the two spans of a two-bearing machine as acting in opposite directions and find the shaft deflection at the loads under this condition. For all cases other than the ones mentioned above, the formula is not exact, but is only a close approximation. Numerical comparisons made in a number of particular cases with the exact formulae for two loads showed very close agreement. As already stated, the formula applies to a shaft with any number of loads. For such cases it was compared with a laborious method of successive approximations given by Stodola,[1] for each of which the agreement was very satisfactory.

The Author. English writers have considered this subjectas a vibration produced by an external disturbance. Their mathematical work has consisted in calculating the natural period ofvibration. Then the shaft can absorb the energy from a synchronous disturbance such as the lash of the belt, the throb of the engine or other driving mechanism and increase the amplitude of the vibration. Dr. Chree pointed out that the centrifugal force arising from a displacement is opposed to the elastic force or the "righting" force of the natural vibration, so that the frequency of vibration is decreased; and that at the critical speed the frequency is zero when the centrifugal force neutralizes the elastic force and there is nothing to restore the original shape.

2 German writers have considered the phenomena as caused by a disturbing force in the system itself, the centrifugal force of the center of gravity of the mass when not exactly coinciding with the center of the shaft, which is always the case in practice.

3 Mathematically, the last supposition has the advantage of showing the amplitude of vibration at speeds other than the critical value, particularly for two loads on the same shaft which show a minimum vibrating speed between two critical speeds.

[1] Stodola's Die Dampfturbinen, 3rd edition, 1905, p. 192.

GENERAL NOTES

INTERNATIONAL RAILWAY CONGRESS

At the opening of the International Railway Congress at the Casino in the city of Berne, Switzerland, the American attendance was much larger than at any other previous congress, excepting that held at Washington in 1905. The Congress was formally opened with an address of welcome in behalf of the Swiss government by the federal counsellor and honorary president of the Congress, M. Forrer, chief of the Department of Post and Railways. He was followed by M. Dubois of Belgium, president of the Congress, who traced briefly the history of the Congress and outlined the work of the present session. The subjects under discussion were, Railways and Waterways, Motor Cars for Passenger Service, Rail Joints, Reinforcement of Permanent Bridges in View of Increased Weight and Speed of Trains, Light Railways and Service by Automobiles and Passenger Tickets.

Six reports on the subject of steel for freight and passenger cars were given at the meeting of Section 2. A long report was presented by Mr. D. F. Crawford, Mem.Am.Soc.M.E., of the Pennsylvania Railroad Company. The greater part of the report deals with freight car construction, and Mr. Crawford pointed out that since 1897 there has been a rapid development in the use of steel for both the parts of freight cars and the entire construction with the result that a great industry had been created.

Among other American delegates present were Mr. F. William Mahl and William R. Webster, both members of the Society. The Congress closed July 14.

AMERICAN PEAT SOCIETY

The American Peat Society held its fourth annual meeting in Ottowa, Canada, July 25–27, 1910, with an interesting program which included the inspection of the fuel-testing plant operated by the Canadian government at Ottowa, which is equipped for testing peat for fuel purposes. Two sessions were devoted to papers presented by Dr. Joseph H. Pratt, State Geologist of North Carolina, Dr. T. A. Mighill, Boston, Mass., Prof. Chas. A. Davis, Peat Expert of the United States Bureau of Mines, M. Max Toltz, St. Paul, Minn., and Prof. R. H. Fernald, Producer Gas Expert of the United States Bureau of Mines.

The arrangements for the meeting were made for the most part under the direction of the president of the society, Dr. Eugene Haanel, Director of the Department of Mines of the Dominion Government.

NATIONAL ASSOCIATION OF MASTER SHEET METAL WORKERS

The National Association of Master Sheet Metal Workers' sixth annual convention was held at Lulu Temple, Philadelphia, Pa., August 10–13. After the formal opening and reports of officials and committees there were lectures on

Wednesday evening on Builders' and Architects' Night illustrated with stereoptican views; The Superiority of Warm Air Heating Systems by Dr. Wm. F. Colbert, the official lecturer of the Federal Furnace League. There were also tests of Toncan Metal by A. T. English; Ingot Iron by J. H. Aurpperle and Tinplate by H. N. Taylor. On Thursday M. G. Sellers gave an address on A Successful Labor Bureau and a committee report followed on How to Obtain Better Prices for New Contract Work. The Friday morning session was opened with an address by Charles S. Prizer, President of the Federal Furnace League, on the relationship between the National Association of Master Sheet Metal Workers and the Federal Furnace League. A report on warm-air furnaces concluded the professional program.

INTERNATIONAL RAILWAY MASTER BLACKSMITHS' ASSOCIATION

A feature of the annual convention of the International Blacksmiths' Association, held in Detroit, Mich., August 16-18 was a trip by special train to Tiffin, Ohio, to visit the works of the National Machinery Company, where over fifty machines were on exhibition most of which were in operation. The machines included forging machines, bolt headers, automatic machines for tapping and burring hot pressed nuts, continuous and automatic rivet machines, vertical roll threaders for handling bolts and long rods, etc. The intention of the visit was to familiarize railway officers and foremen with new designs especially adapted to railway shop service.

SOCIETY OF AUTOMOBILE ENGINEERS

The Society of Automobile Engineers held its summer meeting at Detroit, July 28-31. A great step in advance was made in starting the work of standardizing all things in automobile engineering which would facilitate economic production and benefit the public in both original cost and replacement. This fact was evidenced in the many papers read, among which were Specification and Heat-Treatment of Automobile Material, Henry Souther, Mem.Am.Soc. M.E.; Testing the Hardness of Metal, A. F. Shore; Basis of Motor Car Taxation, Charles T. Terry. Prof. W. H. Bristol, Mem.Am.Soc.M.E., demonstrated some specially prepared apparatus used in connection with the pyrometrical measurement of temperatures in the heat-treatment of steels; F. S. Ward described his new method of grinding spur gears; Eugene P. Batzell presented a paper on his study of slide, rotary and piston valves for gas engines and F. D. Howe summarized for the meeting the matter of ill-smelling and smoky exhausts from gas engines.

AMERICAN SOCIETY OF CIVIL ENGINEERS

A meeting of the American Society of Civil Engineers was held at the Palace Hotel, San Francisco, Cal., August 19. A paper on A Study of the Present Water Supply of the City of Sacramento and a Proposed Means of Improvement was presented by Charles G. Hyde. The following papers were discussed: Pressure Resistance and Stability of Earth, J. C. Meem; Reinforced Concrete Pier Construction, Eugene Klapp; Remedies for Land Slides and Slips on the Kanawha and Michigan Railway, R. P. Black; The Ultimate Load on Pile Foundations: A Static Theory, John H. Griffith.

PERSONALS

George E. Crawley has become connected with the construction department of the Western Union Telegraph Co., New York. Mr. Crawley was until recently associated with the Gold and Stock Telegraph Co., New York.

John T. Croghan has become associated with Stone & Webster Corporation, Pittsfield, Mass. Mr. Croghan was formerly in the employ of the Concord Electric Co., Concord, N. H., as chief engineer.

J. Edmonds Forgy, formerly associated with the E. I. Du Pont de Nemours Powder Co., Wilmington, Del., has accepted a position with the Charles Warner Co. of the same city.

A. L. G. Fritz, recently associated with the Hartford Suspension Co., Jersey City, N. J., as chief draftsman, has become superintendent of construction of the New England Engineering Co., New York.

Albert W. Howe, formerly engineer and representative of the Standard Plunger Elevator Co., New York, has resigned his position to accept that of eastern manager of the H. J. Reedy Co., Cincinnati, O., and has opened an office in New York.

Herman Jakobsson, until recently ordnance designer, Bureau of Ordnance, War Department, Washington D. C., has opened a consulting engineer's office in the same city.

Roy S. King, formerly general superintendent of the Hall-Cronan Co., Dayton, O., is now in the engineering department of the Indiana Steel Co., Gary, Ind.

Thomas H. Mirkill, Jr. has become general manager of the Poole Engineering & Machine Co., Baltimore, Md. Until recently he was connected with the Southward Foundry and Machine Co., Philadelphia, Pa., in the same capacity.

Wm. H. Morse, formerly secretary of the Morgan Construction Co., Worcester, Mass., has become assistant vice-president of the A. Garrison Foundry Co., Pittsburg, Pa.

James O. Pape has severed his connection with the Pittsburg Valve and Fittings Co., Barberton, O., to accept a position with the Chase Grain Co., Chase, Ind.

Geo. M. Peek has accepted the position of mechanical engineer, construction department of the Water Department of St. Louis, Mo.

L. R. Pomeroy, until recently assistant to the president of the Safety Car Heating and Lighting Co., New York, has become chief engineer of the Railway and Industrial Division of J. G. White & Co.

Paul S. Rattle, connected with the Hicks Locomotive & Car Works, Chicago, Ill., will represent that company in Denver, Colo., hereafter.

Edwin B. Ricketts has been appointed supervising engineer of the U. S. Glass Co., Pittsburg, Pa. He was formerly chemist of the New York Edison Co.

Norman B. Roper, formerly identified with the Power & Mining Machinery Co., Cudahy, Wis., as engineer and salesman, has accepted a position with the Cerro de Pasco Mining Co., Peru, South America, in the capacity of mechanical superintendent.

M. W. Sherwood has entered the employ of the Chicago Pneumatic Tool Co., Chicago, Ill. Mr. Sherwood was formerly general inspector of the Board of Aqueduct Commissioners, New York.

Hermann Stephenson has accepted a position with the Brighton Mills, Passaic, N. J. He was formerly instructor of experimental engineering, Cornell University, Ithaca, N. Y.

John A. Stevens has been appointed by Governor Draper to a second term of three years as a member of the Massachusetts Board of Boiler Rules.

Sidney Withington, recently associated with the experimental department of the Walworth Manufacturing Co., South Boston, Mass., has become identified with the electrification department of the New York, New Haven and Hartford Railroad Co., New Haven, Conn.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

American Society of Mechanical Engineers. The Journal. Vol. 32, No. 1–6. *New York, 1910.*

American Society of Municipal Improvement. Proceedings of the 13th annual convention, Birmingham, Ala., October 2–12, 1906. Gift of the Society.

Ciencias Medicas e Higiene. Tomo 2. *Santiago de Chile, 1910.* Gift.

City Planning for Pittsburg. Outline and Procedure. *Pittsburg Civic Commission, 1910.* Gift of J. R. Bibbins.

Engineers Club of Philadelphia. Directory, 1909. *Philadelphia, 1909.* Gift of the Society.

Etude Experimentale du Ciment Armé. By R. Ferret. *Paris, 1906.*

Institut Politechnique de l' Empereur Alexandre II À Kiev. Annales. Book, 1, 1910. *Kiev, 1910.* Gift of Institut Politechnique.

International Railroad Master Blacksmiths' Association. Report of the proceedings of the 16th annual convention, 1908. *Lima, O., 1908.* Gift of the Society.

La France Automobile. Vol. 1–14. 1896–1909. *Paris, 1896–1909.*

Locomotive Actuelle. Etude Generale sur les types recents de locomotives a grande puissance. *Paris, 1906.*

Metropolitan Sewerage Commission of New York. Report, 1910. *New York, 1910.* Gift of the commission.

Michigan Electric Association. Sixth annual convention, August 17–19, 1909. *Detroit.* Gift of the association.

National Commercial Gas Association. Monthly Bulletin. Vol. 1, No. 13–16. *New York, 1910.*

——Proceedings of the 5th Annual Meeting, December 14–17, 1909. *New York, 1909.* Gift of the association.

Natural Gas Association of America. Officers, 1909–1910. Gift of the association.

New York City Docks & Ferries Dept. Report on transportation conditions of the port of New York, with special reference to a joint railroad terminal in Manhattan on the North River above 25th St. *New York, 1910.* Gift of C. Tomkins, Comr. of Docks.

Railway Club of Pittsburg. Proceedings. Vol. 1–7. *Pittsburg, 1901–1908.*

Scranton Engineers Club. Directory, charter and constitution. 1910. *Scranton, 1910.* Gift of the club.

Traveling Engineers Association. Committee reports and subjects for discussion. Eighteenth annual meeting, August 16–19, 1910. *1910.* Gift.

EXCHANGES

American Society of Heating and Ventilating Engineers. Transactions. Vol. 14, 1910. *New York, 1908.*

Municipal Engineers of the City of New York. Proceedings, 1909. *New York, 1909.*

TRADE PUBLICATIONS

Allis-Chalmers Co., *Milwaukee, Wis.* Bull. No. 1054. Allis-Chalmers steam turbines and generators, 43 pp.

Bristol Co., *Waterbury, Conn.* Illustrated catalogue for Bristol's recording instruments for pressure, temperature and electricity, 64 pp.

Broderick & Bascom Rope Co., *St. Louis, Mo.* Underground wire rope haulage as successfully applied in the workings of the Coal Valley Mining Co., Sherrard and Cable, Ill., 25 pp.

Frick Co., *Waynesboro, Pa.* Refrigerating and ice-making machinery, 171 pp.

Handy Index Co., *New York.* Handy Index for architects, engineers, builders and contractors, July 1910, 64 pp.

Industrial Instrument Co., *Foxboro, Mass.* Foxboro Recorder, Vol. 2, No. 3, containing a series of papers about the manufacture and use of instruments, 48 pp.

Lippincott Steam Speciality & Supply Co., *Newark, N. J.* Lippincott faucet, engine indicators, reducing wheels and planimeters, 24 pp.

Manistee Iron Works Co., *Manistee, Mich.* Buttman vertical steam boilers and stokers, 16 pp.

Ohio Brass Co., *Mansfield, O.* Bulletin devoted to electric railway and mine haulage material, 24 pp.

Wm. Wurdack Elec. Mfg. Co., *St. Louis, Mo.* Switches, switchboards panelboards, cabinets and fronts, 11 pp.

UNITED ENGINEERING SOCIETY

New International Year Book, 1909. *New York, Dodd, Mead, & Co., 1910.*

GIFT OF ASSOCIATION OF AMERICAN STEEL MANUFACTURERS

Standard specifications governing the allowable variations in size and weight of hot rolled bars, as adopted by the association, 1910.

Standard specifications governing the chemical and physical properties of bessemer steel rails, as adopted by the association, May 24, 1906.

Standard specifications governing the chemical and physical properties of concrete reinforcement bars, as adopted by the association, 1910.

Standard specifications governing the chemical and physical properties of structural and special open-hearth plate and rivet steel, as adopted by the association, August 9, 1895, revised February 17, 1896, October 23, 1896, April 19, 1902, February 6, 1903.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

043 Lecturer in machine design in university in Canada. Must be a technical graduate and have had experience in the drafting room. Eight months' term, salary $1200.

044 Machine shop foreman, accustomed to the manufacture of heavy machine tools, especially punches, shears, etc. Must have executive ability and be able to produce good work economically.

045 Wanted, in an eastern college, assistant professor of experimental engineering, to take charge of courses in the mechanical laboratory. In replying, state technical education, practical experience, especially in experimental work, and salary expected.

046 Old established manufacturing business needs a business manager, able to take an interest of ten to twenty thousand dollars. Engineering features can be eliminated or separated. Attractive profits have been made for thirty years. Present manager would give part time for one or two year when needed.

MEN AVAILABLE

104 Member, engineer graduate United States Naval Academy. Has served on teaching staff of technical school and university, editorial work, and scientific research for large engineering concern. Wishes responsible position in these or similar lines.

105 Member, with wide experience in engineering, manufacturing and management, soon to complete study of law; desires to connect with law firm, large manufacturers or corporation requiring man of practical and executive ability to handle business involving legal and mechanical work.

106 Young engineer, Junior member, experienced in steel works, industrial engineering; administrative work, steam engineering and operation. Technical graduate.

107 Junior, member technical graduate, desires position as superintendent or assistant, with opportunity to apply broad experience in systematizing and handling men. Mill, foundry or metallurgical work preferred.

108 Graduate Mass. Inst. of Tech. in mechanical engineering; four years' experience in practical shop work, general drafting and minor executive; desires position as draftsman with consulting engineers or assistant superintendent in industrial plant.

109 Junior member, graduate mechanical engineer, experienced manufacturing plant design and installation. At present occupying executive position in manufacturing concern. Desirous of securing similar position in engineering or manufacturing company where chances of advancement are greater. Salary $2400.

110 Member, technical training, 35 years of age. Twelve years excellent experience general machine, foundry and structural business, draftsman, chief draftsman, estimator and travelling engineer. At present, mechanical engineer large machine works and jobbing shops.

111 Experienced civil and mechanical engineer, designing, construction, selling, installation and operation departments of modern power equipment and manufacturing plants; wide personal acquaintance United States, Canada, Great Britain and the continent; successful in dealing with United States and foreign government engineer departments, municipal and other public works; familiar with modern office, shop organization and costs; drafting specifications and contracts; good correspondent and executive; active, energetic and resourceful; eastern Member.

112 General superintendent, mechanical engineer, at present organizing new factory; desires to make change about September 15. Eighteen years executive experience, shop organization and costs, covering machines, tool design and efficiency, production methods, shapes of tools, speeds and feeds, belt tensions and treatments, drop forging and ornamental work, dies of all kinds. Particularly experienced manufacturing machine tools, automobiles and general hardware. Good appearance, very active; highest references. Member, minimum salary, $4000.

113 Technical graduate, over 20 years direct experience in practical affairs of machine shop and foundry. For last 12 years, specialized as superintendent and works manager in modern methods. Demonstrated ability as organizer and executive. Desires position with aggressive growing concern as superintendent or manager; will purchase an interest if desirable.

114 New York member, 30 years' experience designing and superintending manufacture of engines, special and general machinery; power plant, factory revision and installation; process improvement. Desires position with company requiring services of experienced mechanical engineer.

115 Associate, more than fourteen years' drawing room experience; desires to make change, preferably in the East. Would prefer position as checker or squad foreman on rolling mill, steel works, smelting machinery or allied lines.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALEXANDER, Chas. A. (1899; 1905), Engr. and Contr., Bldrs.' Exch., and *for mail,* 64 Cornell St., Rochester, N. Y.

BAENDER, Fred. Geo., (Junior, 1909), Fife, Ore.

BARBIERI, Cesare (1908), Cons. Mech. Engr., Old Colony Bldg., Dearborn & Van Buren Sts., and 921 Leland Ave., Chicago, Ill.

BENSON, Orville (1901), Pequannock, N. J.

BOYD, John T. (1887), 57 Oliver St., Boston, Mass.

BROOKS, Paul R. (1905; 1909), Estate of Jonathan W. Brooks, Mission, Texas.

CASE, Milo McClelland (Junior, 1909), Supt., Champion Mchy. Co., and *for mail,* 163 Illinois St., Joliet, Ill.

COLE, Cyrus L. (Junior, 1908), 549 66th Ave., Milwaukee, Wis.

CORE, W. Wallace (Junior, 1907), Cons. Engr., 165 Sherman Ave., Newark, N. J.

CRAWLEY, George E. (Junior, 1908), Constr. Dept., Western Union Tel. Co., 195 Broadway, and *for mail,* 548 W. 124th St., New York, N. Y.

CROGHAN, John T. (Associate, 1909), Stone & Webster Corp., Box 845, Pittsfield Mass.

CURTIS, Greely, S. (1897; 1904), Marblehead, Mass.

DAWLEY, Clarence A. (Junior, 1904), Cons. Engr., 39 Cortlandt St., New York, N. Y.

FLANDERS, Ralph E. (Associate, 1908), Springfield, Vt.

FOSTER, Horatio A. (1895), 521 San Fernando Bldg., Los Angeles, Cal.

FOX, William (1909), Asso. Prof. Physics, College of the City of N. Y., 139th. St. and Convent Ave., and *for mail,* 575 W. 183rd St., New York, N. Y.

FREDERICK, Floyd Willis (1907), Mech. Engr., Natl. Board of Fire Underwriters, 45 Buckingham Bldg., Waterbury, Conn., and *for mail,* 315 S. Ind. St., Bangor, Pa.

FRITZ, Aime L. G. (Junior, 1907), Supt. of Constr., New England Eng. Co., 50 Church St., New York, N. Y., and *for mail,* 99 Elmwood St., Woodhaven L. I., N. Y.

GERNANDT, Waldo George (Junior, 1910), Factory Engr., Rapid Motor Vehicle Co., and *for mail,* Box 497, Pontiac, Mich.

GRIMM, Paul H. (1890), Cons. Engr. 311 Spring St., New York and Glen Cove, L. I., N. Y.

HAGLUND, Gustav (Junior, 1909), Jamaica Junction, L. I., N. Y.

HALL, Morris A. (1905; Associate, 1906), care New England Automobile Journal, Times Bldg., Pawtucket, R. I.

HILLYER, George, Jr. (1898; Associate, 1904), Broad River Granite Co., Candler Bldg., and *for mail*, 5 Crew St., Atlanta, Ga.

HOWE, Albert W. (1903), Eastern Mgr. H. J. Reedy Co., 111 Broadway, New York, and *for mail*, Hotel St. George, Brooklyn, N. Y.

HURLEY, Daniel (Junior, 1904), Cons. Engr., 1325 M St., N. W., Washington, D. C., and 42 E. Manning St., Providence, R. I.

HUTTON, Mancius S. (Junior, 1908), Junior Salesman, Am. Radiator Co., Bundy Dept., 104 W. 42nd St., and *for mail*, 257 W. 86th St., New York, N. Y.

INSLEE, Heber Clyde (1907), Engr. on Plant Work, Babcock & Wilcox Co., Bayonne, N. J.

JAKOBSSON, Herman (1907), Cons. Engr., 303 Victor Bldg., 724 Ninth St. N. W., and 3 Stanley Apts., Harvard St., Washington, D. C.

JOHNSTONE, Francis W. (1909), The Natl. Iron & Steel Wks., S. A., Calzada de los Gallos, Mexico City, Mexico, D. F.

KING, Roy S. (1904; 1910), Engr. Dept., Indiana Steel Co., and *for mail*, 609 Jefferson St., Gary, Ind.

LARKIN, Everett P. (Junior, 1906), 372 Bement Ave., West New Brighton, S. I., N. Y.

LAVERY, Geo. L. (1886), 3019 Indiana Ave., and 4300 Ellis Ave., Chicago, Ill.

LEA, Henry I. (1906; 1909), Cons. Gas Engr., 1517 People Gas Bldg., and 6129 Winthrop Ave., Chicago, Ill.

McINTOSH, William (1902), 25 Willow Ave., Plainfield, N. J.

MAROT, Edward H. (Junior, 1903), Hyatt Roller Bearing Co., Newark, and *for mail* 5 Jefferson Ave., South Orange, N. J.

MERSHON, Ralph D. (1900), Cons. Engr., 60 Wall St., New York, N. Y.

MILLER, Herman G. (1908), Armstrong Mchy. Co., Spokane, Wash.

MIRKIL, Thomas H., Jr. (1884), Genl. Mgr., Poole Engr. & Mah. Co., Woodberry, Baltimore, Md.

MITCHELL, Chas. J. (1908), Ch. Draftsman, Fairbanks, Morse Mfg. Co., and *for mail*, 825 Park Ave., Beloit, Wis.

MORSE, William Horace (1901; 1903), Asst. V. P., A. Garrison Fdy. Co., Pittsburg, Pa.

MUMFORD, Edgar Huidekoper (1887; 1892), 27 Compton Ave., Plainfield, N. J.

NORBOM, John O. (1900), Min. Engr., Alta Vista, Berkeley, Cal.

OWENS, Robert B. (Associate, 1892), Secy., Franklin Inst., Philadelphia, Pa.

PAPE, James Otto, (Junior, 1908), Chase Grain Co., Chase, Ind.

PEEK, George Meredith (1892; 1900), Mech. Engr., Constr. Dept., Water Wks., and *for mail*, 5623 Bartmer Ave., St. Louis, Mo.

POMEROY, L. R. (1890; 1909), J. G. White & Co. Inc., 43 Exchange Pl., New York, N. Y., and 24 Reynolds Terrace, Orange, N. J.

RAPLEY, Frederick Harvey (1905), M. Clark & Co., 9 New Broad St., London, England.

RATTLE, Paul S. (Junior, 1908), Rep., Hicks Loco. & Car Wks., 801-17th St., Denver, Colo.

RICKETTS, Edwin B. (Junior, 1908), Supervising Engr., The U. S. Glass Co., 9th and Bingham Sts., and 5901 Alder St., Pittsburg, Pa.

ROPER, Norman Brownell (1905), Mech. Supt., Cerro de Pasco Mining Co., La Fundicion, Peru, S. A.

SARGENT, Chas. E. (1891), 530 Marine Bldg., Chicago, Ill.

SERGEANT, Chas. H. (1895), 57 Rose St., New York.

SHERWOOD, Mather Williams (1909), Chicago Pneumatic Tool Co., Fisher Bldg., Chicago, Ill.

SLOMER, Wm. Frederick (1909), 61 W. Canfield St., Detroit, Mich.

SMITH, William E. (Junior, 1908), Box 95, College Corner, O.

SPRADO, Ralph (1900), Ch. Engr., Dow Pumping Eng. Co., San Francisco, and *for mail*, 911 Grand St., Alameda, Cal.

STEENSTRUP, P. S. (1906), Jacksonville, Ore.

STEPHENSON, Hermann (Junior, 1909), Brighton Mills, Passaic, N. J.

STIMSON, Oscar M. (1906), O. M. Stimson & Co., 1335 Old Colony Bldg., Chicago, Ill.

SYMONS Wilson E. (1899), 900 Postal Telegraph Bldg., Chicago, Ill.

THORNTON, William F. (1909). Mechanicsburg, Cumberland Co., Pa.

THURSTON, George H. (1902), Asst. Mech. Engr., Consol. Goldfields of South Africa, 8 Old Jewery, London, England.

TRASK, Walter H., Jr. (Junior, 1908), Denver Engr. Wks. Co., and *for mail* 845 Pennsylvania Ave., Denver, Colo.

WEEKS, Paul (Junior, 1905), Needles, Cal.

WELLS, J. Barnard (Junior, 1909), Draftsman, A. T. & S. F. Ry. and *for mail*, 301 S. Boyle Ave., Los Angeles, Cal.

WILEY, James M. (Junior 1909), Elec. Engr., Holly Sugar Co., and *for mail*, Swink, Colo.

WILLISTON, Arthur L. (1896; 1899), care W. W. Simmons, 102 Bay St., Manchester, N. H.

WINTERROWD, William H. (Junior, 1907), Asst. Engr. Mech. Dept., N. Y. Central Lines, and *for mail*, The Arden, E. 18th St., Cleveland, O.

WITHINGTON, Sidney (Junior, 1908), Elec. Dept., N. Y. N. H. & H. R. R. Co., New Haven, Conn.

NEW MEMBERS

ABRAHAMS, M. Landa (Junior, 1910), Inspr. of Mchy., Isthmian Canal Com., Washington, D. C.

ADAMS, John (Junior, 1910), Estimator, Otis Elev. Co., New York, and *for mail*, 4093 Ferris St., Woodhaven, L. I., N. Y.

CUNNINGHAM, George H. (Junior, 1910), Draftsman, Va. Bridge & Iron Co., and *for mail*, Box 487, Roanoke, Va.

DuBARRY, Ed. G., (Junior, 1910), Pittsburg Valve and Fittings Co., and *for mail*, 5321 Penn Ave., Pittsburg, Pa.

CARTER, Harold Thomas (Junior, 1910), Engr., Water Works, Aish Bagh, Lucknow, India.

GLADFELTER, Herbert S. (Junior, 1910), Inspr., Mech. Engr. in charge Levee Mch. with Civil Service, Modoc, Ark.

HENDERSON, Clark T. (Junior, 1910), Elec. and Mech. Engr., Cutler Hammer Mfg. Co., Milwaukee, Wis.

PORTER, Hollis P. (1910), Pres. and Mgr., Schlafli & Porter Co., Engrs., 206 Stewart Bldg., Houston, Texas.

PRICE, William T. (Junior, 1910), Phila. Rep., De La Vergne Mch. Co., 380 Bourse Bldg., Philadelphia, Pa., and Glen Lake, Pitman, N. J.

ROBINSON, Mark (1909), care Mrs. Huntington, 1 Canning St., Waterloo, nr. Liverpool, England.

ROSS, Philip Lawrence (Junior, 1910), Proposition Dept., Babcock & Wilcox Co., Bayonne, and *for mail*, 40 Milford Ave., Newark, N. J.

PROMOTIONS

HENES, Louis G. (1903; Associate, 1910), Mgr., Manning, Maxwell & Moore, Inc., Mgr., Commer. Acetylene Co., Mgr., Ry. Materials Co., 247-249 Monadnock Bldg., San Francisco, and Key Route Hotel, Oakland, Cal.

MAHL, F. W. (1892; 1910), Asst. to Dir. Maintenance and Operation, Union Pacific System and Southern Pacific Co., 135 Adams St., Chicago, and *for mail*, 1019 Michigan Ave., Evanston, Ill.

DEATHS

CLARK, Charles B., March 24, 1910.
DUNCAN, J. D. E., July 13, 1910.
FAULKS, James B., Jr., July 14, 1910.

GAS POWER SECTION

CHANGES OF ADDRESS

BAENDER, Fred. Geo. (1909), Mem.Am.Soc.M.E.
CRAWLEY, George E. (1908), Mem.Am.Soc.M.E.
DAWLEY, Clarence A. (1908), Mem.Am.Soc.M.E.
LEA, Henry I. (1908), Mem.Am.Soc.M.E.
MITCHELL, Chas. J. (1909), Mem.Am.Soc.M.E.
MORDEN Chas. Whitney (Affiliate, 1909), 586 Everett St., Portland, Ore.
SARGEANT, Chas. E. (1908), Mem.Am.Soc.M.E.
SERGEANT, Chas. H. (1908), Mem.Am.Soc.M.E.
TYLEE, Don O. (Affiliate, 1909), 755 Franklin Ave., Wilkinsburg, Pa.

STUDENT BRANCHES

CHANGES OF ADDRESS

BASS, L. D. (Student, 1910), Canton, Ill.
BECK, George, Jr., (Student, 1909), 95 Sussex Ave., East Orange, N. J.
BENBOW, J. R. (Student, 1910), 529 High St., Pottstown, Pa.
BERGER, Julius G. (Student, 1909), 104 S. Common St., Lynn, Mass.
BOLGIANO, J. R. (Student, 1909), Security Cement & Lime Co., Security Md.
BOWER, F. A. (Student, 1909), 547 Hancock St., Brooklyn, N. Y.
BUTLER, W. C. M. (Student, 1910), Park Pl., Schuylkill Co., Pa.
CHILDS, J. N. (Student, 1909), Y. M. C. A., Hazelton, Pa.
COLGATE, G. M. (Student, 1910), 509 Erie Ave., Niagara Falls, N. Y.
COMINS, Harold N. (Student, 1909), 701 Whitney Ave., Wilkinsburg, Pa.
COOK, George C. (Student, 1909), 32 Vine St., West Lynn, Mass.
CRANE, Fred L. (Student, 1909), 413 Rebecca Ave., Wilkinsburg, Pa.
DORER, Oscar H. (Student, 1909), 418 Whitney Ave., Wilkinsburg, Pa.
FAIRCHILD, F. P. (Student, 1910), 586–68th Ave., West Allis, Wis.
GARY, F. P., (Student, 1910), Southern Cotton Oil Co., Augusta, Ga.
GLEASON, E. P. (Student, 1910), 2408 Wells St., Milwaukee, Wis.
GRIMES, C. E. (Student, 1909), 113 S. 37th St., Philadelphia, Pa.
GUNKEL, Fred H., Jr., (Student, 1909), Westwood, N. J.
HAM, C. W. (Student, 1910), 215 Arlington Ave., Lexington, Ky.
HARDING, H. C., (Student, 1909), 34 Linden Ave., Middletown, N. Y.
HATMAN, J. G. (Student, 1910), Wyandotte County Gas Co., Kansas City, Kan.
HEISLAR, C. S. (Student, 1909), 1951 S. Homan Ave., Chicago, Ill.
HODGSON, J. H. S., (Student, 1910), 1421 Arch St., Philadelphia, Pa.
JEHLE, Ferdinend (Student, 1909), Heine Safety Boiler Co., 2449 E. Marcus Ave., St. Louis, Mo.
JONAS, M. R. (Student 1909), 2401 Chelsea Ave., Baltimore, Md.
KERR, Geo. W. (Student, 1910), 754 Ross Ave., Wilkinsburg, Pa.
KONSTANKEWICZ, M. J. (Student, 1910), 629 Adams St., Gary, Ind.
LAY, R. P. (Student, 1910), 302 Coolidge Ave., Syracuse, N. Y.
MERRIHEW, L. A. H. (Student, 1910), 86 Oak St., Plattsburg, N. Y.
MEYER, Richard C. (Student, 1909), 119 W. Lanvale St., Baltimore, Md.
MUFFLY, Walter W. (Student, 1910), 21 Chestnut St., Sharon, Pa.
PAGE, W. K. (Student, 1909), 618 Chapel St., Schenectady, N. Y.
ROBINSON, G. E. (Student, 1910), 860 Huntington Ave., Boston, Mass.
SCHUSTER, George (Student, 1909), 324 McLean St., Lincoln, Ill.
SERRELL, John J. (Student, 1909), 81 Myrtle Ave., Plainfield, N. J.

SPOOR, I. H. (Student, 1910), 360 Wisconsin Ave., Oshkosh, Wis.
THOMAS, Felix (Student, 1910), 310 W. 2d St., Dayton, O.
TORRANCE, C. Everett (Student, 1909), 105 Hudson St., Ithaca, N. Y.
WESLEY, Chas. F. (Student, 1909), Box 148, 1421 Arch St., Philadelphia, Pa.
WHAREN, Geo. B. (Student, 1910), 405 Paige St., Schenectady N. Y.
WHEDBEE, Edgar (Student, 1909), 437 N. 5th St., Terre Haute, Ind.
WOHLENBERG, W. J. (Student, 1910), 456 Swissvale Ave., Wilkinsburg, Pa.
WORKMAN, D. M. (Student, 1910), 5 Oak St., Aurora, Ill.

NEW MEMBERS

CORNELL UNIVERSITY

ORBISON, T. E. (Student, 1910), 699 Lawrence St., Appleton, Wis.

PURDUE UNIVERSITY

COFFIN, T. (Student, 1910), 1018 State St., W. Lafayette, Ind.
GREEN, J. B. (Student, 1910), R. F. D. 14, Trenton, N. J.
KELLEY, P. W. (Student, 1910), 1008 E. Charles St., Muncie, Ind.
KING, Clifford M. (Student, 1910), Centerville, Ind.
MILLS, J. L. (Student, 1910), 817 Claremont Ave., Chicago, Ill.
SAUERS, John L. (Student, 1910), Tate St., Lawrenceburg, Ind.
SMITH, T. C. (Student, 1910), Chalmers, Ind.
TEMPLIN, E. W., Student, 1910), Univ. of Ill., Urbana, Ill.
WIEST, H. N. (Student, 1910), 172 Juneau Ave., Milwaukee, Wis.

UNIVERSITY OF NEBRASKA

BURLEIGH, W. H. (Student, 1910), 104 Oneida Ave., Davenport, Ia.

COMING MEETINGS

SEPTEMBER—OCTOBER

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN MINING CONGRESS
September 26–October 1, annual convention, Los Angeles, Cal. Managing director, Sidney Norman.

AMERICAN PUBLIC HEALTH ASSOCIATION
September 5–9, annual meeting, Milwaukee, Wis. Secy., W. C. Woodward, Washington, D. C.

AMERICAN SOCIETY OF CIVIL ENGINEERS
September 7, 220 W. 57th St., New York, 8.30 p.m. Paper: Remedies for Landslides and Slips on the Kanawha and Michigan Railway, R. P. Black. Secy., C. W. Hunt.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENT
October 11–16, annual convention, Erie, Pa. Secy., Prescott Folwell, 239 W. 39th St. N. Y.

AMERICAN STREET AND INTERURBAN RAILWAY ASSOCIATION
October 10–14, annual convention, Atlantic City, N. J. Secy., H. C. Donecker, 29 W. 39th St., New York.

ASSOCIATION OF EDISON ILLUMINATING COMPANIES
September 6–8, annual meeting, Thousand Islands, N. Y. Asst. Secy., Walter Neumuller, 55 Duane St. New York.

THE COLORADO ELECTRIC LIGHT, POWER AND RAILWAY ASSOCIATION
September 21–23, annual convention, Glenwood Springs, Secy., F. D. Monis, 323 Hagerman Bldg., Colorado Springs.

INTERNATIONAL ASSOCIATION OF MUNICIPAL ELECTRICIANS
September 6–9, annual convention, Rochester, N. Y. Secy., Frank B. Foster, Corning.

INTERNATIONAL CONGRESS OF HIGHER TECHNICAL EDUCATION
September 9–11, Brussels, Belgium. Comr., Elmer Ellsworth Brown. Bureau of Education, Department of Interior, Washington, D. C.

INTERNATIONAL CONGRESS OF REFRIGERATION
October 9–12, University of Vienna, Austria. Papers: Constructing and Testing Refrigeration Machinery and Insulating Materials, Application of Refrigeration to Food, Industrial Refrigeration, Railway and Steam-

ship Refrigeration, Legislation and Administration. Chairman of Committee on Transportation, F. W. Pilsbury, 1660 Monadnock Block, Chicago, Ill.

INTERNATIONAL HUNTING CONGRESS

September 5-7, Vienna, Austria. Secy., C. Kunsby, Wiesingerstrasse 8.

INTERNATIONAL MUNICIPAL CONGRESS AND EXPOSITION

September 18-30, Chicago, Ill. Secy., Curt M. Treat, 1107-1108 Great Northern Bldg.

IRON AND STEEL INSTITUTE

September 26-30, Buxton, England. Secy., G. C. Lloyd, 28 Victoria St., London, S. W.

LEAGUE OF AMERICAN MUNICIPALITIES

August 23-26, annual convention, St. Paul, Minn. Secy., John MacVicar, Desmoines, Iowa.

MASTER CAR AND LOCOMOTIVE PAINTERS' ASSOCIATION

September 13-16, annual convention, St. Louis, Mo. Secy., A. P. Dane, Reading, Mass.

MICHIGAN GAS ASSOCIATION

September 9-12, annual meeting, aboard boat "Georgian Bay." Secy. Glenn R. Chamberlain, Grand Rapids, Mich.

NATIONAL ASSOCIATION OF GERMAN-AMERICAN TECHNOLOGISTS

September 1-5, Newark, N. J. Paper: The Activity of Radium and Permanency of the Element with Side-Lights on Transmutation and Alchemy, L. H. Friedburg. Secy., B. A. von Bergen, 842 Broad St.

NATIONAL ASSOCIATION OF STATIONARY ENGINEERS

September 12-17, annual convention, Rochester, N. Y. Secy., Fred W. Raven, 325 Dearborn St., Chiacgo, Ill.

NATIONAL CONSERVATION CONGRESS

September 6-9, St. Paul, Minn. Secy., Thomas R. Shipp, Colorado Bldg., Washinton, C. D.

NATIONAL IRRIGATION CONGRESS

September 26-30, annual meeting, Pueblo, Colo., Secy., Arthur Hooker.

NAVAL, MERCANTILE, MARINE AND GENERAL ENGINEERING MACHINERY EXHIBITION

September 1-16, Olympia, London, England. Secy. Frederic W. Bridges, 119-125 Finsburg Pavement, London E. C.

NEW ENGLAND WATERWORKS ASSOCIATION

September 21-23, annual convention, Rochester, N. Y. Secy., Willard Kent Narragansett Pier, R. I.

PACIFIC COAST GAS ASSOCIATION

September 20-22, annual meeting, Los Angeles, Cal. Secy., John A. Britton, 925 Franklin St., San Francisco.

ROADMASTERS AND MAINTENANCE OF WAY ASSOCIATION

September 13-16, Chicago, Ill. Secy., W. E. Emery, West Chicago.

UNION OF CANADIAN MUNICIPALITIES

August 31-September 2, annual convention, Toronto, Ont. Secy., W. D. Lighthall, K. C., Westmount, Que.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
September			P. M.
1	Blue Room Engineering Society	W. D. Sprague	8.00
2	Western Union Electrical Society	H. C. Northen	7.00
7	Wireless Institute	S. L. Williams	7.30
8	Illuminating Engineering Society	P. S. Millar	8.00
9	Western Union Electrical Society	H. C. Northen	8.15
16	Western Union Electrical Society	H. C. Northen	7.00
16	New York Railroad Club	H. D. Vought	7.00
23	Western Union Electrical Society	H. C. Northen	7.00
28	Municipal Engineers of New York	C. D. Pollock	8.15
28	Western Union Electrical Society	H. C. Northen	7.00
October			
5	Wireless Institute	S. C. Williams	7.30
6	Blue Room Engineering Society	W. D. Sprague	8.00
7, 14, 21, 28	Western Union Engineering Society	H. C. Northen	7.00
11	American Society of Mechanical Engineers	C. W. Rice	8.15
13	Illuminating Engineering Society	P. S. Millar	8.15
18	New York Telephone Society	T. H. Lawrence	8.00
19, 20, 21	American Gas Institute	A. B. Beadle	All day
21	New York Railroad Club	H. D. Vought	8.15
26	Municipal Engineers of New York	C. D. Pollock	8.15

OFFICERS AND COUNCIL

PRESIDENT

George Westinghouse .... Pittsburg, Pa.

VICE-PRESIDENTS

Geo. M. Bond .... Hartford, Conn.
R. C. Carpenter .... Ithaca, N. Y.
F. M. Whyte .... New York

Terms expire at Annual Meeting of 1910

Charles Whiting Baker .... New York
W. F. M. Goss .... Urbana, Ill.
E. D. Meier .... New York

Terms expire at Annual Meeting of 1911

PAST-PRESIDENTS

Members of the Council for 1910

John R. Freeman .... Providence, R. I.
Frederick W. Taylor .... Philadelphia, Pa.
F. R. Hutton .... New York
M. L. Holman .... St. Louis, Mo.
Jesse M. Smith .... New York

MANAGERS

Wm. L. Abbott .... Chicago, Ill.
Alex. C. Humphreys .... New York
Henry G. Stott .... New York

Terms expire at Annual Meeting of 1910

H. L. Gantt .... New York
I. E. Moultrop .... Boston, Mass.
W. J. Sando .... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft .... Philadelphia, Pa.
James Hartness .... Springfield, Vt.
H. G. Reist .... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

William H. Wiley .... New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt .... New York

HONORARY SECRETARY

F. R. Hutton .... New York

SECRETARY

Calvin W. Rice .... 29 West 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

ALEX. C. HUMPHREYS, *Chairman*
CHAS. WHITING BAKER, *Vice-Chairman*
F. R. HUTTON
H. L. GANTT
F. M. WHYTE

STANDING COMMITTEES

FINANCE

ARTHUR M. WAITT (5), *Chairman*
ROBERT M. DIXON (3), *Vice-Chairman*
EDWARD F. SCHNUCK (1)
GEO. J. ROBERTS (2)
WALDO H. MARSHALL (4)

HOUSE

WILLIAM CARTER DICKERMAN (1), *Chairman*
FRANCIS BLOSSOM (3)
BERNARD V. SWENSON (2)
EDWARD VAN WINKLE (4)
H. R. COBLEIGH (5)

LIBRARY

JOHN W. LIEB, JR. (3), *Chairman*
LEONARD WALDO (2)
AMBROSE SWASEY (1)
CHAS. L. CLARKE (4)
ALFRED NOBLE (5)

MEETINGS

WILLIS E. HALL (5) ,*Chairman*
L. R. POMEROY (2)
WM. H. BRYAN (1)
CHAS. E. LUCKE (3)
H. DE B. PARSONS (4)

MEMBERSHIP

CHARLES R. RICHARDS (1), *Chairman*
GEORGE J. FORAN (3)
FRANCIS H. STILLMAN (2)
HOSEA WEBSTER (4)
THEO. STEBBINS (5)

PUBLICATION

D. S. JACOBUS (1), *Chairman*
FRED R. LOW (3)
H. F. J. PORTER (2)
GEO. I. ROCKWOOD (4)
GEO. M. BASFORD (5)

RESEARCH

W. F. M. GOSS (4), *Chairman*
R. H. RICE (2)
R. C. CARPENTER (1)
RALPH D. MERSHON (3)
JAS. CHRISTIE (5)

NOTE—Numbers in parentheses indicate number of years the member has yet to serve

SPECIAL COMMITTEES

1910

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
G. T. Voorhees
A. P. Trautwein
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Chas. Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
F. R. Hutton
G. M. Basford
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
L. D. Burlingame
Charles Whiting Baker
M. L. Holman
Calvin W. Rice

On International Standards for Pipe Threads

E. M. Herr, *Chairman*
Geo. M. Bond
William J. Baldwin
Stanley G. Flagg, Jr.

On Standards for Involute Gears

Wilfred Lewis, *Chairman*
E. R. Fellows
Hugo Bilgram
C. R. Gabriel
Gaetano Lanza

Nominating Committee

Robert M. Hunt, *Chairman*
F. F. Gaines
Geo. M. Basford
E. M. Herr
W. H. V. Rosing

On Power Tests

D. S. Jacobus, *Chairman*
L. P. Breckenridge
Edward F. Miller
Edward T. Adams
William Kent
Arthur West
George H. Barrus
Charles E. Lucke
Albert C. Wood

On Student Branches

F. R. Hutton, Honorary Secretary

On Arrangements for Joint Meeting in England

Ambrose Swasey, *Chairman*
Chas. Whiting Baker, *Vice-Chairman*
Geo. M. Brill
John R. Freeman
W. F. M. Goss

Members Ex Officio

George Westinghouse, President
F. R. Hutton, Honorary Secretary
William H. Wiley, Treasurer
Calvin W. Rice, Secretary
Willis E. Hall, Chairman Meetings Committee

SOCIETY REPRESENTATIVES

1910

On John Fritz Medal

AMBROSE SWASEY (1) — CHAS. WALLACE HUNT (3)
F. R. HUTTON (2) — HENRY R. TOWNE (4)

On Board of Trustees United Engineering Societies Building

F. R. HUTTON (1) — FRED J. MILLER (2)
JESSE M. SMITH (3)

On Library Conference Committee

J. W. LIEB, JR., CHAIRMAN OF THE LIBRARY COMMITTEE, AM.SOC.M.E.

On National Fire Protection Association

JOHN R. FREEMAN — IRA H. WOOLSON

On Joint Committee on Engineering Education

ALEX. C. HUMPHREYS — F. W. TAYLOR

On Advisory Board National Conservation Commission

GEO. F. SWAIN — JOHN R. FREEMAN
CHAS. T. MAIN

On Council of American Association for the Advancement of Science

ALEX. C. HUMPHREYS — FRED J. MILLER

NOTE—Number in parentheses indicate number of years the member has yet to serve.

OFFICERS OF THE GAS POWER SECTION

1910

CHAIRMAN
J. R. Bibbins

SECRETARY
Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman (1), *Chairman*
F. R. Hutton (3)
G. I. Rockwood (2)
H. H. Suplee (4)
F. R. Low (5)

GAS POWER MEMBERSHIP COMMITTEE

H. R. Cobleigh, *Chairman*
A. F. Stillman
H. V. O. Coes
G. M. S. Tait
A. E. Johnson
George W. Whyte
F. S. King
S. S. Wyer

GAS POWER MEETINGS COMMITTEE

Wm. T. Magruder, *Chairman*
Nisbet Latta
W. H. Blauvelt
H. B. MacFarland
E. D. Dreyfus
C. W. Obert
A. H. Goldingham
C. T. Wilkinson

GAS POWER LITERATURE COMMITTEE

C. H. Benjamin, *Chairman*
L. S. Marks
G. D. Conlee
T. M. Phetteplace
R. S. de Mitkiewicz
G. J. Rathbun
L. V. Goebbels
R. B. Bloemeke
L. N. Ludy
A. L. Rice
A. J. Wood

GAS POWER INSTALLATIONS COMMITTEE

L. B. Lent, *Chairman*
A. Bement
C. B. Rearick

GAS POWER PLANT OPERATIONS COMMITTEE

I. E. Moultrop, *Chairman*
C. N. Duffy
J. D. Andrew
H. J. K. Freyn
C. J. Davidson
W. S. Twining
C. W. Whiting

GAS POWER STANDARDIZATION COMMITTEE

C. E. Lucke, *Chairman*
E. T. Adams
Arthur West
James D. Andrew
J. R. Bibbins
H. F. Smith
Louis C. Doelling

Note—Number in parentheses indicate number of years the member has yet to serve.

MEETINGS OF THE SOCIETY

THE MEETINGS COMMITTEE

WILLIS E. HALL (5), *Chairman* L. R. POMEROY (2)
WM. H. BRYAN (1) CHAS. E. LUCKE (3)
H. deB. PARSONS (4)

Meetings of the Society in Boston

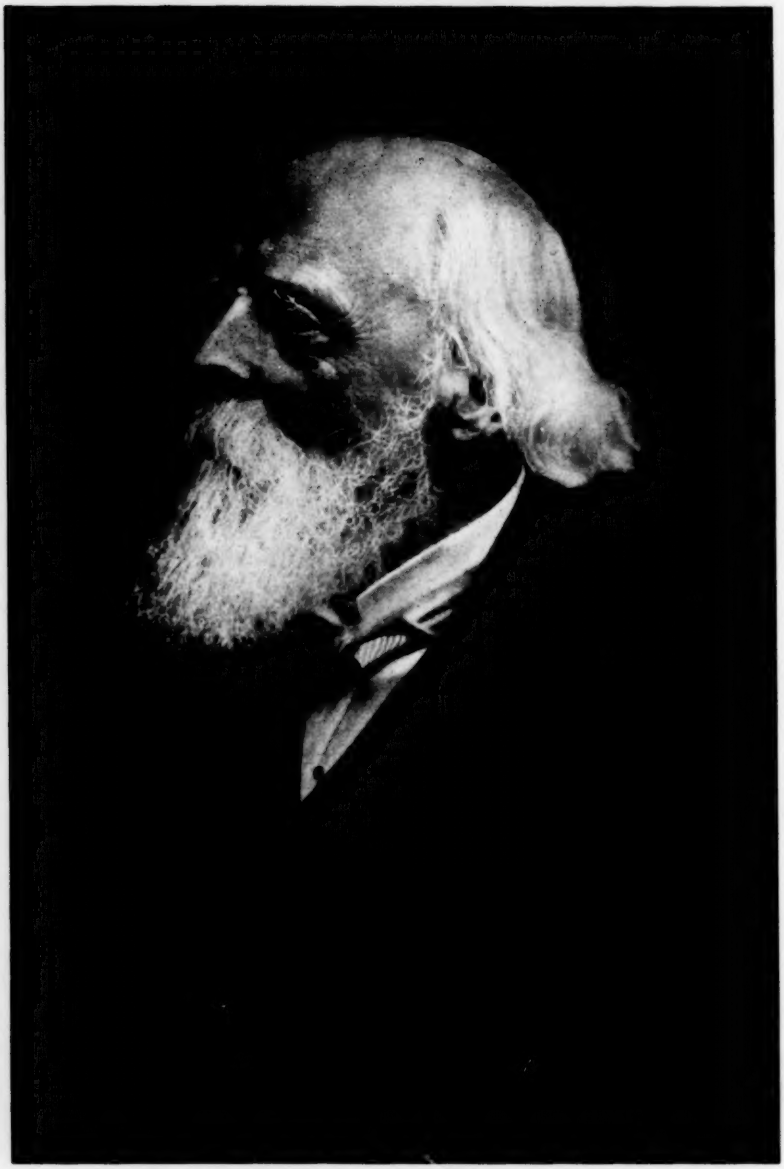
IRA N. HOLLIS, *Chairman* I. E. MOULTROP, *Secretary*
EDWARD F. MILLER J. H. LIBBEY

Meetings of the Society in St. Louis

WM. H. BRYAN, *Chairman* ERNEST L. OHLE, *Secretary*
R. H. TAIT, *Vice-Chairman* FRED E. BAUSCH
M. L. HOLMAN

OFFICERS OF STUDENT BRANCHES

INSTITUTION	BRANCH AUTHORIZED BY COUNCIL	HONORARY CHAIRMAN	PRESIDENT	CORRESPONDING SECRETARY
	1908			
Stevens Inst. of Tech., Hoboken, N. J.	December 4	Alex. C. Humphreys	H. H. Haynes	R. H. Upson
Cornell University, Ithaca, N. Y.	December 4	R. C. Carpenter	C. C. Allen	C.F. Hirschfeld
	1909			
Armour Inst. of Tech., Chicago, Ill.	March 9	G. F. Gebhardt	F. E. Wernick	W. E. Thomas
Leland Stanford Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	A. F. Meston	J. B. Bubb
Polytechnic Institute, Brooklyn, N. Y.	March 9	W. D. Ennis	J. S. Kerins	Percy Gianella
State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
Purdue University, Lafayette, Ind.	March 9	L. V. Ludy	H. A. Houston	J. M. Barr
University of Kansas, Lawrence, Kan.	March 9	P. F. Walker	C. E. Johnson	C. A. Swiggett
New York Univ., New York	November 9	C. E. Houghton	Harry Anderson	Andrew Hamilton
Univ. of Illinois, Urbana, Ill.	November 9	W. F. M. Goss	B. L. Keown	C. S. Huntington
Penna. State College, State College, Pa.	November 9	J. P. Jackson	G. B. Wharen	G. W. Jacobs
Columbia University, New York.	November 9	Chas. E. Lucke	F. R. Davis	H. B. Jenkins
Mass. Inst. of Tech., Boston, Mass.	November 9	Gaetano Lanza	Morrill Mackenzie	Foster Russell
Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	H. B. Cook	C. J. Malone
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	John S. Langwill	Karl L. Kraatz
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. V. Aycock	Osmer Edgar
Univ. of Nebraska, Lincoln, Neb.	December 7	C. R. Richards	W. J. Wohlenberg	W. H. Burleigh
	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	B. N. Wilson	C. B. Boles	W. Q. Williams



Chas T. Porter

HONORARY MEMBER
OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS